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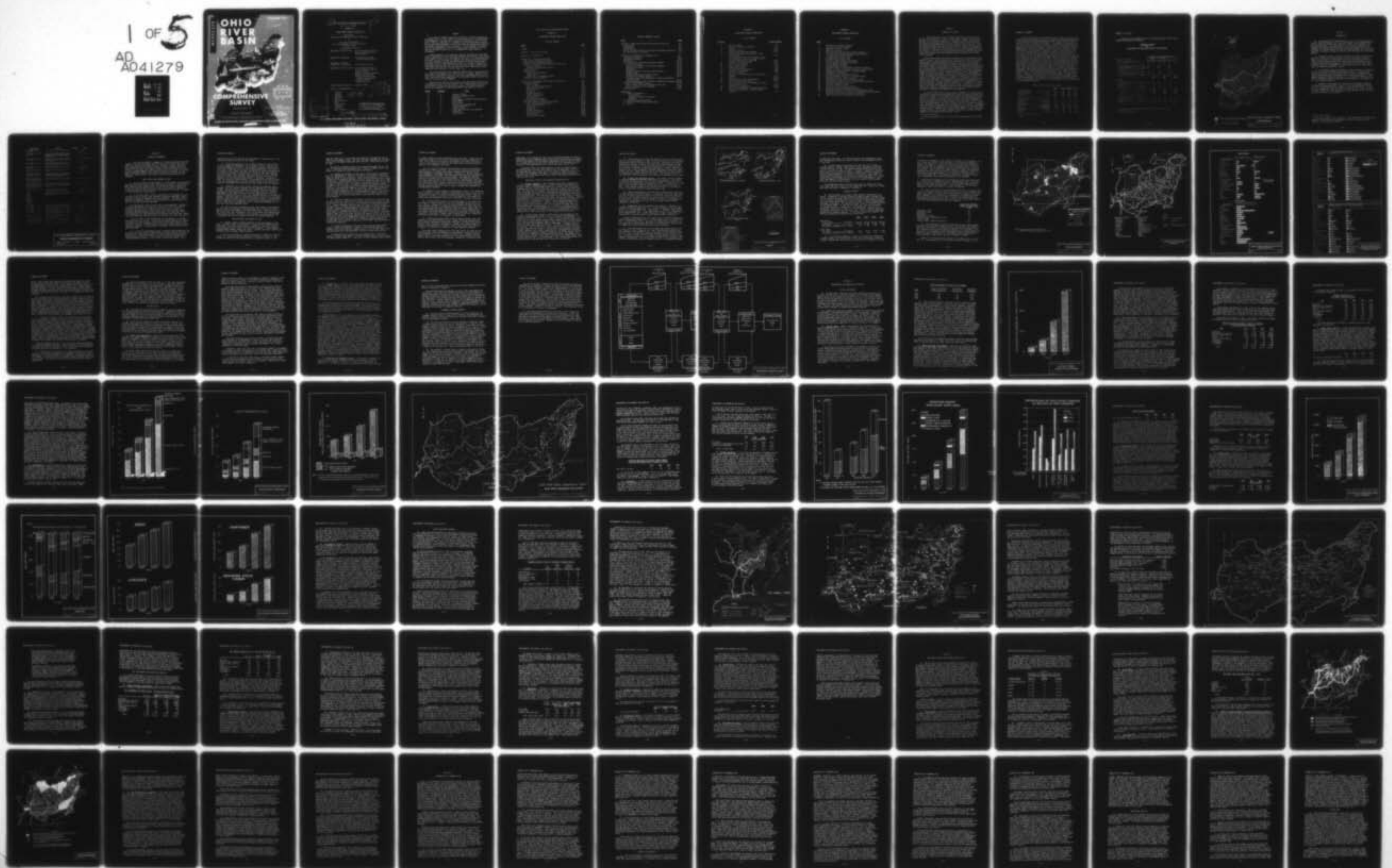

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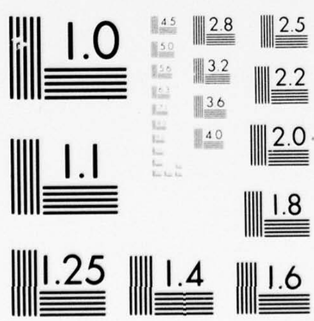

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VOLUME XII

OHIO RIVER BASIN

COMPREHENSIVE SURVEY

Appendix K

DEVELOPMENT PROGRAM FORMULATION

Prepared for
The Ohio River Basin Survey Coordinating Committee
by
The Corps of Engineers
U.S. Army Engineers, Ohio River
in cooperation with the participating
Federal and state agencies.

OHIO RIVER BASIN SURVEY COORDINATING COMMITTEE

OHIO RIVER BASIN COMPREHENSIVE SURVEY.

Volume XII.

APPENDIX K.

DEVELOPMENT PROGRAM FORMULATION.

prepared for
The Ohio River Basin Coordinating Committee

by

The Corps of Engineers
U.S. Army Engineer Division, Ohio River
Cincinnati, Ohio

in cooperation with the

Department of Agriculture:	Soil Conservation Service Economic Research Service Forest Service
Department of Commerce:	Environmental Science Services Administration
Department of Health, Education, and Welfare:	Public Health Service
Department of the Interior:	U.S. Geological Survey Fish and Wildlife Service Bureau of Mines Bureau of Outdoor Recreation National Park Service Federal Water Pollution Control Administration Southeastern Power Administration
Federal Power Commission:	Bureau of Power

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Indiana
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PREFACE

This appendix presents background information, planning concepts and procedures, and, as an end product, a generalized plan for the development and management of the water and related land resources of the Ohio River Basin. The plan, comprised of a framework of broad-scaled water resource and related program elements, outlines the water and related land resource development requirements within the basin. It also accounts for general land use and management practices and water based or enhanced activities that may influence, benefit by, or be dependent on water resource development.

Program elements of the framework plan were progressively formulated through integration of the various developmental opportunities and alternatives judged to best fulfill the needs of the basin. The plan demonstrates the extent to which the water and related land resources can meet present and future demands for water and water-oriented functions and services, the manner in which these demands can be met, the timing and magnitude of development required, and the cost that would be involved. Elements outlined herein form the basis for the Ohio River Basin development program summarized and discussed in the *Main Report*.

The various agencies which cooperated and assisted in the preparation and review of this appendix are listed on the title page. Members of the Coordinating Committee for the Ohio River Basin Comprehensive Survey and their staffs contributed immeasurably to the review of drafts and the resolution of varied views and comments.

Findings of the various participating State and Federal agencies and information and data from their reports - all integral parts of the study and essential to the plan formulation process - are summarized herein; details are documented in other appendices to the report as follows:

VOLUME	APPENDIX	TITLE
II	A	History of Study
III	B	Projective Economic Study
IV	C	Hydrology
V	D	Water Supply and Water Pollution Control
VI	E	Ground Water
VII	F	Agriculture
VIII	G	Fish and Wildlife Resources
IX	H	Outdoor Recreation
X	I	Electric Power
XI	J	State Laws, Policies, and Programs
XIII	L	Navigation
XIV	M	Flood Control

OHIO RIVER BASIN COMPREHENSIVE SURVEY

APPENDIX K

DEVELOPMENT PROGRAM FORMULATION

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SECTION I

SUMMARY OF FINDINGS

1. The region under study, 163,000 square miles of the Ohio River Basin[1] shown in figure 1, is rich in land, water, mineral, and other resources. Its 19 million residents in 1960 made up nearly 11 percent of the Nation's population; their skills, finances, and initiative provide the requisites indispensable to productive use of these resources. From the time of discovery by LaSalle in the late 17th century to the present, the Ohio Basin region has contributed much to the economic well-being of our nation. If the basin is to continue in this role, comprehensive plans for efficient short- and long-range development and use of water and related land resources must be formulated and then carried out by timely action programs.

Present water-resource-oriented programs must be accelerated and expanded in scope to satisfy the need for flood control, water supply, water quality control, land management, outdoor recreation, fish and wildlife enhancement, navigation, hydroelectric power, and other water-related services required to sustain and improve the socio-economic well-being of the region. Water use and demand for related functions and services existent in 1965 should be multiplied by the following factors to reflect the projected 2020 needs: electric energy requirements, 13 times; waterborne freight ton-miles, 5.4 times; recreation-days, 6.3 times; stream assimilation of organic wasteloads, 2.9 times; prevention of flood damages, 2.7 times; municipal and industrial water supply withdrawal, 2.5 times; sport fishing, 2.4 times; and hunting, 1.3 times. A rising trend in public desires for preservation and enhancement of environmental factors and aesthetic values will require increased consideration of these aspects of resource planning. To meet increasing demands, it is essential to control and use available resources more efficiently than in the past. It is apparent that control of streamflows and regionwide coordinated development and use of streams and impounded waters will play an important role in planning for meeting future demands on the resources.

By 2020 the total annual surface water withdrawals in the Ohio Basin study area, including the nonconsumptive portion returned to streams, will be about 64 percent of the average annual volume of streamflow of the Ohio River at its mouth. Excluding the flow volumes from the Tennessee River, Ohio River streamflow will about equal the Ohio study area withdrawals. Annual consumptive use will be equivalent to about one-half inch of runoff over the drainage area. Many small streams go dry in the summer, and, at other locations, streamflows are insufficient for daily needs. Supplemental flows are therefore required to assure adequate supplies. At other times, excessive runoff creates floods causing severe damage. Greater control of surface flows will be required throughout the basin to provide the water needed for the projected socio-economic growth.

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[1] Further reference to the Ohio River Basin encompasses the study area only.

SUMMARY OF FINDINGS

2. Provision for efficient control and use of water resource and related lands will encompass a variety of projects and management programs at all governmental and nongovernmental levels requiring significant investments in all subregions of the basin. The demands for products and services directly or indirectly related to control of floodflows will require the provision of about 10 million acre-feet of storage by the year 1980 and over 33 million by 2020, in addition to the 17 million in the 1965 program. Low flow control needs will require correspondingly 6.8 and 19.1 million acre-feet of installed storage in addition to the 7.1 million provided by the going program. About one million acre-feet of this future low flow storage requirement would be supplied from joint use of storage for high flow control by 1980, and over 3 million, by 2020 making it necessary to construct 5.8 and 16.1 million acre-feet of storage for low flow by the reported time periods. The impounded waters and improved quantities and quality of waters in flowing streams will provide by 2020 outdoor recreation and fish and wildlife resource opportunities for about 500 million recreation-days, or nearly 45 percent of the total demand. About 35 percent of the basin lands are in potential upstream watershed projects and about 50 percent are in need of land treatment and management. To meet the demands for food and fiber by 2020, 4 million acres of lands in the basin would need drainage, and 1.3 million supplemental irrigation. The flood plain information studies included in the program will provide a general base for a flood plain management program Extensive development for hydroelectric power generation, modifications to existing waterways, and provision of new waterways are also major items in the development program.

GROSS DEMAND FOR WATER AND RELATED FUNCTIONS AND SERVICES

	1965 Year Value	Total Demand 1980	2000	2020
Water Supply (Withdrawals):				
Municipal and Industrial. . . . . . .million gallons per day. .	11,553	14,035	19,357	28,251
Farm Domestic and Livestock . . . . do. . .	162	168	231	294
Rural, Nonfarm Domestic . . . . do. . .	587	673	794	934
Irrigation. . . . . do. . .	46	102	352	682
Electric Power Cooling. . . . . do. . .	19,200	29,000	46,000	63,000
Mining. . . . . do. . .	289	511	974	1,894
Residual[1] Organic Wasteload				
Assimilation. . . . . million population equivalents. .	4.6	6.0	8.8	13.4
Average Annual Residual				
Flood Damage. . . . . .million dollars. .	111	144	205	296
Navigation. . . . . .billion ton-miles. .	27.3	49.3	90.5	147.4
Hydroelectric Power,				
Installed Capacity. . . . . .megawatts. .	1,500	7,200	20,100	40,000
Outdoor Recreation. . . . . .million recreation-days. .	220	391	710	1,030
Sport Fishing . . . . .million angler-days. .	21.8[2]	35.2	40.7	51.8
Hunting . . . . .million hunter-days. .	21.7[2]	25.5	26.6	28.6
Commercial Fishing. . . . . million pounds. .	2.5	14.2	20.9	27.5
Land Treatment and				
Management. . . . . .million acres. .	3.4	21.8	42.9	54.5
Drainage. . . . . do. . .	12.1	15.3	16.2	16.6
Irrigation. . . . . do. . .	.09	.22	.77	1.42

(1) Assumes 85 percent removal of wastes.

(2) 1960 Use.

SUMMARY OF FINDINGS

In addition to the capabilities of the going programs, the following resource developments are needed:

FRAMEWORK PROGRAM FOR DEVELOPMENT OF WATER AND RELATED LAND RESOURCES

	Cumulative, in Addition to 1965 Program					
	To 1980		To 2000		To 2020	
STREAMFLOW CONTROL AND IN-STREAM USE	Amount	Cost (billion dollars)	Amount	Cost (billion dollars)	Amount	Cost (billion dollars)
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use...........million acre-feet..	5.80	1.40	8.70	2.18	16.11	3.96
2. Control of Floodflows.....................................		2.76		4.37		9.10
a. Reservoir and Detention Storage......million acre-feet..	9.99		15.89		33.37	
b. Local Protection Projects........................miles..	152		320		488	
c. Channel Improvement...............................do....	2,394		3,037		6,328	
d. Flood Plain Information Studies......number of studies..	200		450		700	
3. Navigable Waterways.......................................		.47		1.59		1.81
a. Improvements to Existing Waterways...billion ton-miles..	8.65		45.60		99.52	
b. Potential New Waterways...........................do....	1.17		4.52		6.05	
4. Hydroelectric Power, Installed Capacity..........megawatts..	7,200	.81	20,100	2.21	40,000	4.50
Total..		5.44		10.35		19.37
RELATED PROGRAMS						
1. Outdoor Recreation, Sport Fishing, and Hunting.............................million man-days..	132.7	0.46	199.1	0.70	494.6	1.72
2. Watershed Land Treatment(1) and Management..............................million acres..	11.4	.29	25.6	.63	29.2	.73
3. Lands to be Irrigated(2)....................million acres..	.1	.01	.7	.06	1.3	.12
4. Lands to be Drained(2).......................million acres..	3.2	.42	3.8	.51	4.0	.54
Total..		1.18		1.90		3.11
Grand Total..		6.62		12.25		22.48
Remaining demands - To be met by affiliated programs.						
1. Outdoor Recreation, Sport Fishing, and Hunting.............................million man-days..	179.5	0.64	449.5	1.58	471.4	1.64
2. Additional Land Treatment and Management.................................million acres..	7.0	.17	13.8	.35	21.9	.55
Total..		.81		1.93		2.19

(1) Includes land treatment and management in potential watershed projects, above potential storage reservoirs, and critical erosion areas.

(2) Preparation of lands and onfarm facilities.

OHIO BASIN STUDY AREA

TVA STUDY AREA

OHIO RIVER BASIN COMPREHENSIVE SURVEY
OHIO RIVER BASIN
CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION
APPENDIX K FIGURE 1

SECTION II

INTRODUCTION

3. In accordance with Senate Document No. 97,[1] a principal objective in water resource planning "is to provide the best use, or combination of uses, of water and related land resources to meet all foreseeable short- and long-term needs." To accomplish this in an expanding economy, the framework studies analyze past accomplishments and present and future requirements and compare them with unused or underused water and related land resources to develop a program for the efficient satisfaction of projected demands.

4. Framework studies, to be most effective as guides for action programs and to serve as a sound base for a continuing planning process, should be both broad in coverage and flexible in structure so that additional alternative courses of action may be examined, evaluated, and instituted as desirable or necessary. Formulation of the Ohio River Basin framework program of development has been accomplished with these planning goals and reporting objectives in mind.

5. This appendix explains the bases for and techniques in formulating the Ohio River Basin framework development program. It gives the basic facts concerning the past and present status of water and related land resource development and a projected view of future requirements. A development program is formulated to present, by time periods, the goals and initial development costs to meet the projected demands of the people and for their economic endeavors.

6. Appendix K was prepared by integrating the cooperative efforts of the participating agencies. Figure 2 lists the cooperating agencies with their assignments and contributions to the planning effort. In addition, a summary of studies on minerals and mining and a brief inventory of scenic, historical, and archeological themes relevant to the Ohio River Basin are attached to this appendix.

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[1] Policies, Standards, and Procedures in the Formulation, Evaluation, and Review of Plans for Use and Development of Water and Related Land Resources. 87th Congress, 2d Session.

Cooperating Agency	Assignment	Appendix	Title
U.S. Army Engr Div, Ohio River, Corps of Engrs	Summary findings, Ohio River Comprehensive Survey.		Main Report
U.S. Army Engr Div, Ohio River, Corps of Engrs	History of the investigation, including pertinent assignments, dates, policy guidance, legislative action and summaries of meetings of the Coordinating Committee.	A	History of Study
U.S. Army Engr Div, Ohio River, Corps of Engrs	Projections of population, industrial activity and gross national product for the Ohio River Basin and its subareas.	B	Projective Economic Study
U.S. Army Engr Div, Ohio River, Corps of Engrs	Basic climatologic and hydrologic data for use in the report. Frequency of flood and low flow and surface water availability.	C	Hydrology
Federal Water Pollution Control Administration	Water supply needs, organic waste loads and water pollution control needs.	D	Water Supply and Water Pollution Control
U.S. Geological Survey, Dept of Interior	Geologic conditions as related to aquifers and their yield.	E	Ground Water
Soil Conservation Service, Economic Research Service, and Forest Service, Department of Agriculture	Current and future needs for agriculture and the problems and potential solutions as related to water and related land development with emphasis on land treatment and management	F	Agriculture
Bureau of Sport Fisheries and Wildlife and Bureau of Commercial Fisheries, Fish and Wildlife Service, Dept of Interior	Needs and potentials for fishing and hunting and the utilization of the resource for their fulfillment.	G	Fish and Wildlife Resources
Bureau of Outdoor Recreation, Dept of Interior (includes a report by National Park Service on historical, archeological, and scenic resources)	Present and future demands for outdoor recreation, the use and potential of present facilities and guides for utilization of the Basin's recreation resource areas.	H	Outdoor Recreation
Federal Power Commission, Bureau of Power	Existing and future electric power supply and requirements, thermal power cooling needs.	I	Electric Power Resources and Requirements
Illinois Indiana Kentucky Maryland New York North Carolina Ohio Pennsylvania Tennessee Virginia West Virginia	Prepare a report on *State Laws, Policies, and Programs* and make an inventory of non-federal water resources facilities.	J	*State Laws, Policies and Programs*
U.S. Army Engr Div, Ohio River, Corps of Engrs	Plan for development of the Basin's resources to satisfy the needs for water and related activities.	K	Development Program Formulation
U.S. Army Engr Div, Ohio River, Corps of Engrs	Present and future demands for waterborne commerce and related waterway needs.	L	Navigation
U.S. Army Engr Div, Ohio River Corps of Engrs	Present and future flood control needs. Analyze the present plan and develop a program for additional flood damage reduction.	M	Flood Control
National Park Service, Dept of Interior	Aesthetic, historical, archeological and cultural themes for use in Appendix K.	Attached to Appendix K	
Bureau of Mines, Dept of Interior	Data on minerals and mining for use in Appendix K.	Attached to Appendix K	
Environmental Science Services Administration, Dept of Commerce	Standard project storm and data on climatology.	Used in Appendices C,K, & M	
U.S. Geological Survey, Dept of Interior	Streamflow data, extended rating curves.	Used in Appendices C & M	

OHIO RIVER BASIN COMPREHENSIVE SURVEY

REPORT ASSIGNMENTS BY AGENCIES

CORPS OF ENGINEERS U. S. ARMY OHIO RIVER DIVISION

APPENDIX K **FIGURE 2**

SECTION III

PLANNING ENVIRONMENT

7. This section presents a summary of the early exploration and settlement of the Ohio River Basin and historical beginnings of water and related land resource development and use. Physical, climatic, and hydrologic characteristics of the basin related to water resources needs and availability are given, and economic factors which are the basis for present and projected demands on the resources are briefly covered. Historical events and accomplishments help explain the present status and set the stage for future planning. Law, policy, and planning concepts are also discussed.

EARLY SOCIAL AND ECONOMIC HISTORY

8. Early exploration and settlement of the Ohio Basin followed natural waterroutes from the Atlantic Coast and the Gulf of Mexico to the interior. Many immigrants were already highly trained and were seeking communities in which to practice their skills and invest their savings. Important attractions were the fertile lands and the availability of water for domestic and farm use and transportation.

9. At one time, many of the skilled workers at Pittsburgh, Pa., at the head of the Ohio River, were reported to have been employed in making boats which served the westward settlement movement. Iron smelting and foundries for domestic utensils, tools, machine parts, steam engines, and nails for settlers were also developed.

Fort Washington, now Cincinnati, Ohio, was strategically located on the Ohio River opposite the mouth of Kentucky's Licking River, between Pittsburgh and the Falls of the Ohio at Louisville, Ky. Initially Cincinnati developed into a trading center, but a skilled labor supply attracted important manufacturing, such as early iron foundries, which later developed into fabricated metals and machine tool industries. Brewing, food processing, publishing, and printing activities also grew rapidly.

Louisville owes its early development to the necessity to portage around the Falls of the Ohio. Travellers replenished supplies and stopped for repairs and other services while transferring to other boats to continue their journey. Although primarily a trading center, important manufacturing, especially of wood products, developed. Distilleries also became significant.

10. In the early development period, raw goods were shipped down the Ohio and Mississippi Rivers to New Orleans and then by coastal shipping to eastern towns. Goods manufactured in Eastern States were shipped across the Appalachian Mountains to Pittsburgh and then down the Ohio River to towns throughout the basin. Thus, a trade triangle was created. High

overland shipping costs prompted the development of factories west of the Appalachian mountains within the Ohio Basin.

11. Pittsburgh, because of its strategic location at the junction of the Allegheny and Monongahela Rivers, became a site of intense industrial and commercial activity. Iron furnaces, shipyards, textile mills, glass works, breweries, and distilleries were established. Availability of iron ore, coal, timber, and water transportation greatly encouraged and facilitated the growth of manufacturing. Access to the Great Lakes ore fields by low-cost water transport and then a short rail haul, combined with nearby fossil-fuel resources, made the Pittsburgh area one of the greatest iron- and steel-producing centers in the world. Abundance of water for processing, waste disposal, and transportation of both raw materials and finished products was a significant factor in the location of industrial development at Pittsburgh and other places along the waterways.

12. Youngstown, Ohio, had a history similar to Pittsburgh, being founded in 1797 by settlers from New York who operated the first smelter in 1802. Native bog ores, limestone, and charcoal from local forests, combined with water availability, were significant factors in the early development of the steel industry. With the opening of the first coal mine in the Mahoning Valley in 1826, coal replaced charcoal in the smelting process. Today both sides of the Mahoning River in the vicinity of Youngstown are lined with steel mills for a distance of 25 miles. The Mahoning Valley of eastern Ohio and western Pennsylvania has been called the "Little Ruhr." Steel centers at Wheeling, W. Va., Ironton and Middletown, Ohio, and other localities developed later.

13. During the early settlement period, towns grew up also along the National Road, which extended from Cumberland, Md., through the northern part of the Ohio River Basin to the Mississippi River. Columbus, Ohio, on the Scioto River, and Indianapolis, Ind., on the White River, became major cities along the road. Railroads, paved highways, and pipelines followed this general route as the industrial corridor to the west developed.

WATER RESOURCE DEVELOPMENT HISTORY

14. Pioneers readily adapted themselves to the physiography of the basin. However, nature's inconsistency in supplying man's needs was soon recognized. The rivers often shoaled in summer and froze over in winter, which endangered water supplies and impaired navigation. Floods damaged business establishments, homes, and crops. Droughts resulted in insufficient harvests; water shortages created hardships.

In 1817 the Legislature of Indiana incorporated a company to construct a canal to solve the navigation problems at the Falls of the Ohio. The project was started but not completed due to a washout failure. A toll

canal was later built by a private stock company on the Kentucky side of the falls and opened in 1830. The facilities were expanded over the years, and in 1874 the Federal Government took them over. Tolls were abolished in 1880.

The earliest cooperative effort at resource development was for control of floodflows along the Wabash River. There, in 1808, private landowners built levees to protect farmlands from flooding.

15. Federal participation in the basin's water resource development was first implemented in 1824 with the removal of sand bars in the Ohio River to improve it for navigation. Later, growing needs for river transportation led to extensive channel clearing on the Ohio River and its major tributaries. Increased barge traffic of bulk commodities resulted in 1885 in the construction of the first Federal lock and dam at Davis Island, near the head of the Ohio River. The needs of waterborne commerce prompted Congress in 1910 to authorize a 9-foot navigable channel in the Ohio River. A series of locks and dams together with channel improvements provided by 1929 a navigable depth of 9 feet throughout the river. Construction of these works was accompanied by a like development on many of the tributaries. A number of the original structures have since been replaced with more efficient facilities to keep pace with the growing volume of waterborne commerce.

16. With the movement of the pioneers into the Ohio Valley came the grist and saw mills. One of the first mills was built in Indiana in 1784, at the Falls of the Ohio, while in 1789 another was located near Marietta, Ohio. Streams throughout the basin were utilized to drive water wheels for small mills, and people drove horses and wagons for miles to have their products processed. The development of electricity in the 19th century brought electric generating stations, many dependent upon water power, which began to accelerate the industrial growth of the region. The importance of water use by the power industry soon began to shift from falling water which turned turbines and generators to the vast quantities of water now required for cooling steamelectric generation plants. The availability of huge quantities of low-cost electric power has been responsible for bringing many new industries to the basin, particularly the manufacture of aluminum and chemicals.

17. Water was originally obtained directly from springs, shallow wells, and natural streamflows. However, as concentrated demands increased, central distribution systems were built; and in many cases, storage and pumping works were developed to better use available supplies.

The availability of streams for waste disposal was a significant factor in economic development. Resulting deterioration of stream quality has been a major concern for a long time, but most organized public actions

to control stream pollution have taken place since 1940. A major step was the establishment of the Ohio River Valley Water Sanitation Commission in 1948. Eight States and the Federal Government joined hands to abate pollution by encouraging and requiring the construction of municipal and industrial waste treatment facilities.

18. As a result of droughts, exploitation of soils by overcropping, and other poor farming practices, soil and water conservation practices became necessary to sustain the economic production of food and fiber. Land treatment and management practices, including soil erosion prevention, water management, and productivity maintenance practices were developed to protect and maintain the land resources base. Such measures involving individual landowners were later supplemented by the Watershed Protection and Flood Prevention Act of 1954, Public Law 566, 83d Congress, and amendatory legislation brought Federal assistance to sponsors of watershed protection projects which, besides providing for flood prevention, conservation storage, and other beneficial uses of water, included land treatment and land management measures.

19. Because of the increase in population and higher living standards, public interest in outdoor recreation, enhancement of fish and wildlife, and the aesthetic value of our natural resources has grown widely. Major advances have been made in National and State programs to give greater consideration to environmental factors which previously had been undervalued.

20. The widespread flood of 1913 prompted people in the Great Miami River Basin in Ohio to take the first major organized regional action for flood control. Between 1915 and 1920, without Federal or State aid, the Miami Conservancy District pioneered construction of five major flood control detention dams and local protection works at several communities. In 1934 the Muskingum Watershed Conservancy District in Ohio sponsored and, with Federal and State cooperation, planned and developed 14 flood control reservoirs in the basin. Federal funds allocated by the Public Works Administration were used for a large part of the program.

21. Following the great floods of March 1936 and January 1937, comprehensive plans were formulated, and a Federal basinwide comprehensive water resource development program was undertaken. Although flood control was the primary purpose of the reservoir system, other purposes were included. The program also provided for local flood protection projects to supplement the protection by reservoirs at many population centers.

The survey reports preceding the 1938 Flood Control Act were the last that formulated a basin development plan designed to mitigate Ohio River system problems as a basis for project authorization. However, numerous reports covering individual subbasins and local problems concerning flood control, water supply, pollution abatement, recreation, fish and wildlife

enhancement, and hydroelectric power have since been submitted to Congress. These reports have recommended many projects which were approved by Congress and are incorporated into the present comprehensive plan for the Ohio Basin. All of these resulting projects are alternatives to or supplement projects included in the comprehensive plan of the Flood Control Act of 1938.

Interstate, State, and county agencies, as well as those of municipalities and other political subdivisions, such as conservancy districts and watershed and flood control districts, have all played an active role in project and management development. They are taking an increasingly important part in the basin's water and related land resource planning programs and activities.

PHYSICAL, CLIMATIC, AND HYDROLOGIC CHARACTERISTICS

22. Physical features. - The Ohio Basin study area includes major portions of Ohio, Indiana, Kentucky, and West Virginia; the western third of Pennsylvania; the southeastern portion of Illinois; parts of northern Tennessee; and small areas of New York, Maryland, Virginia, and North Carolina. The study area is bounded on the north by the Great Lakes drainage area, on the east by the divide of the Appalachian Mountains, on the south by the Tennessee River Basin, and on the west by the watershed draining to the Mississippi River. The area to the north of the Ohio River is primarily a glaciated plain of minor relief where deep, fertile soils prevail. Unglaciated portions in the northern area and all of the area south of the Ohio River are hilly to mountainous. The Ohio River drainage encompasses a total of 203,910 square miles. However, the Tennessee River basin, with 40,910 square miles, though a part of the Ohio River drainage area, has been excluded from the study except for its effects on controlling flows in the Ohio River. The Tennessee Basin is one of the designated water resource regions under the national program for comprehensive river basin planning and is under the purview of the Tennessee Valley Authority.

23. The Ohio River, formed at Pittsburgh by the confluence of the Allegheny and Monongahela Rivers, flows in a generally southwesterly direction for 981 miles to Cairo, Ill., where it joins the Mississippi. The flood plain is rather narrow, ranging from an average width of less than a mile in the Pittsburgh-Wheeling reach to more than a mile in the Cincinnati-Louisville reach and broadening somewhat downstream. Throughout most of the flood plain, about one-fourth mile of its width is normally occupied by the river. The limited valley lands, including much of the flood plain, are used intensively by industry. The Kanawha, Little Kanawha, Big Sandy, Licking, Kentucky, Salt, Green, Cumberland, and Tennessee Rivers entering from the south are generally deeply entrenched, the rugged terrain limiting the location of communities and transportation routes. The Beaver, Muskingum, Hocking, Scioto, Little Miami, Great Miami, and Wabash Rivers flowing from the north are in glaciated areas. Their valleys are shallow, relatively broad for the most part, and suitable for agriculture.

24. Ninety-four million acres (90 percent) of land in the Ohio River Basin is in private ownership. About 50 million acres of this is cropland and pastures forming the agricultural land base. The basin also contains extensive forests and is one of the significant minerals-producing areas of the world. Except for a small mountainous section in North Carolina and Virginia, the bedrock surfaces are sedimentary. Mineral resources are primarily coal, clay, sandstone, limestone, petroleum, natural gas, sand, gravel, and salt. These resources are the raw materials on which hundreds of industries throughout the basin are based. This industrial activity has generated a thriving economy, which requires large quantities of water.

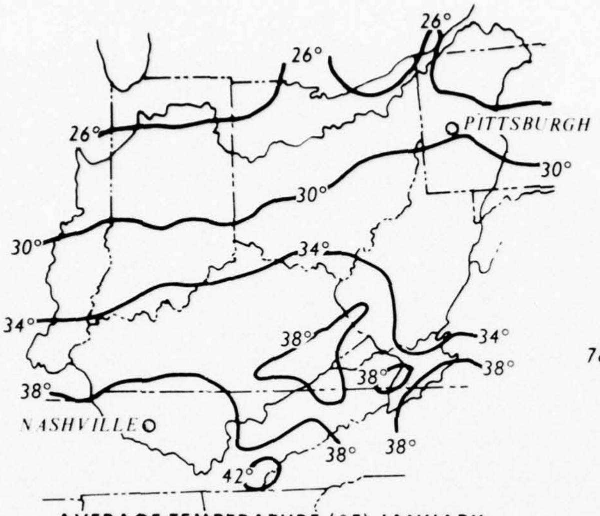
25. Climatic and hydrologic factors. - Ohio Basin climate is marked by moderate extremes of heat and cold, dryness and wetness. The weather is seasonal and changeable, but the climate is generally desirable in regard to both personal comfort and economic activity. The basin lies in the path of the continental weather systems that pass usually from west to east. Abrupt weather changes occur frequently owing to the influence of shifts in the Arctic and Gulf of Mexico airmass flows.

26. Summers are moderately warm and humid, creating ideal conditions for one or more agricultural harvests. The average frost-free season varies from 200 days in the south part of the basin to 120 days in the northeast part, with extremes having varied from 247 days in the former to 73 in the latter. Choice of crops and number of plantings in one season are regulated by these factors, as well as by soil types, precipitation, topography, and markets.

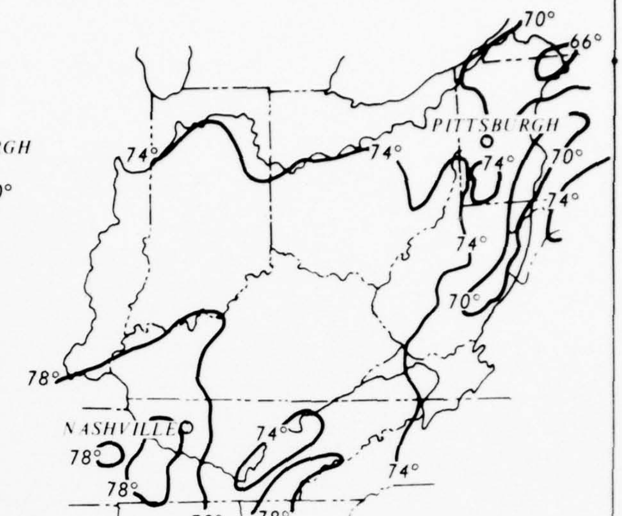
27. Temperatures vary with elevation and location. Generally, July temperature averages range from 70° F. in the northeast part of the basin to 80° F. in the southwest part. (See figure 3.) However, summer temperatures have exceeded 100° F., and several days of over 90° F. temperatures can be expected each year. Summer temperatures create a demand for air conditioning, increasing electric power needs and water consumption.

Winters are moderately cold with several days of subzero temperatures. January temperatures average 40° F. in the southern parts of the basin to 26° F. in the northern parts. Basinwide ice problems are infrequent; but ice occasionally causes oxygen deficiency in surface waters, and ice jams on streams can cause flood problems and hinder navigation.

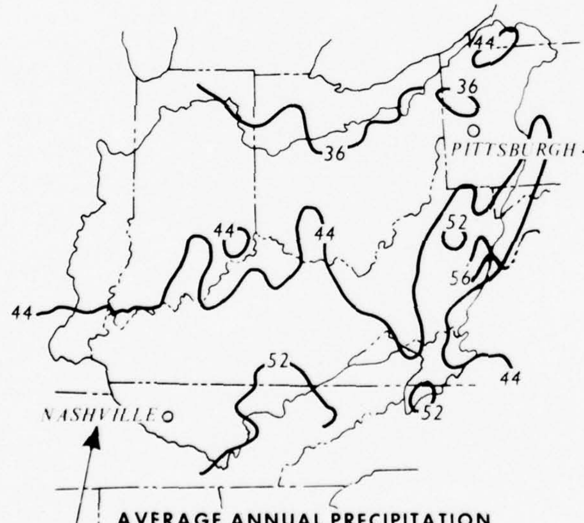
28. Storm occurrences vary, with extreme floods seldom covering the entire basin during the same period. Major flood-producing storms occur most frequently from December to April when soils are saturated and runoff is high. Over 8 million acres have been inundated by past floods of record. A series of storms in 1937 produced the most destructive basin flood. Frequent thunderstorms often yield intense rainfalls which cause soil erosion and flashflooding on small streams and result in considerable damage



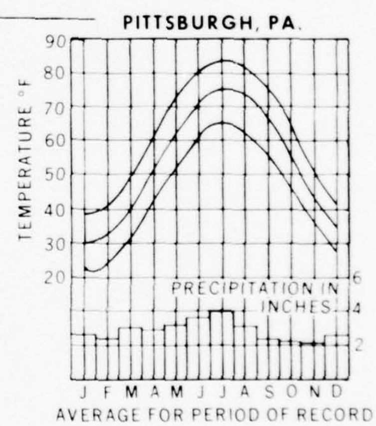
AVERAGE TEMPERATURE (°F) JANUARY

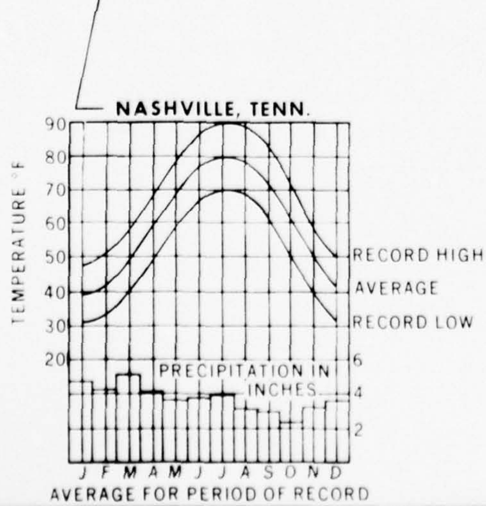


AVERAGE TEMPERATURE (°F) JULY

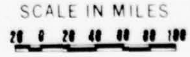


AVERAGE ANNUAL PRECIPITATION
(Inches)





SCALE IN MILES



OHIO RIVER BASIN COMPREHENSIVE SURVEY

CLIMATE

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE 3

to towns and rural areas. Hurricane-associated rains occasionally pass over the Appalachian Mountains causing floods in the southeastern portion of the basin.

29. The mean annual precipitation over the basin is 45 inches, including snowfall. However, precipitation varies considerably with location and from year to year. The greatest average monthly precipitation occurs in June or July, and the least, in October. Snowfalls in the basin may be heavy but are usually followed by thawing periods which generally leave no large accumulation for melting in the spring. Crop yields are often reduced by droughts, but harvests are seldom completely lost. Evapotranspiration often exceeds precipitation in the growing season. Therefore, peak demand for supplementary irrigation normally occurs between early July and the middle of August.

Low streamflows affecting quantity and quality of water supply and other water uses occur usually in late summer and fall. Details on climate and runoff are given in "Appendix C: Hydrology."

ECONOMIC FACTORS

30. The Ohio Basin is an area of great economic importance to the Nation. Strategically situated between the populous East, the Upper Mississippi Valley, the Great Lakes, and the Southern Atlantic and Gulf States, it is a source of raw materials and agricultural and manufactured products and also a major market area for industrial goods. Table 2 presents major land uses in the basin. The regional economy is one of the most diversified in the United States. In 1960 the Ohio Basin had 19 million residents, 10.6 percent of the U.S. population. The average basin density of 116 persons per square mile is double that of the Nation. Figure 4 shows the population distribution over the study area. Table 1 gives the population projections by economic subareas. The following tabulation presents 1960 data and projections on population and labor force:

	1960	1980	2000	2020
Population:				
United States.............thousands..	180,000	245,000	331,000	430,000
Ohio Basin....................do....	19,300	23,300	29,000	35,300
Ohio Basin....percent of U.S. total..	10.6	9.4	8.7	8.2
Labor force:				
Ohio Basin................thousands..	7,020	8,700	11,200	14,800
Ohio Basin....percent of U.S. total..	9.5	8.6	7.6	7.4

31. To facilitate assessment of water and related land resource development needs, the Ohio Basin was divided into 19 hydrologic subbasins. Economic subareas were then selected to approximate the subbasins in order

to establish the demands of each subbasin's economy on its resources. Figure 5 shows the relation of the boundaries of the economic subareas to those of the subbasins. Population, labor force, and other economic projections are given in "Appendix B: Projective Economic Study." Tables 3 and 4 provide 1960 and projected labor force, employment, and industrial output data. Figure 6 shows the subarea shares of present and projected population and the interrelationships of subbasin economies in terms of manufacturing employment shares of 1960 totals and 1960-2020 gains. Figure 7 shows expansions of the economy as related to increases in water supply requirements and wasteloads generated in each subarea.

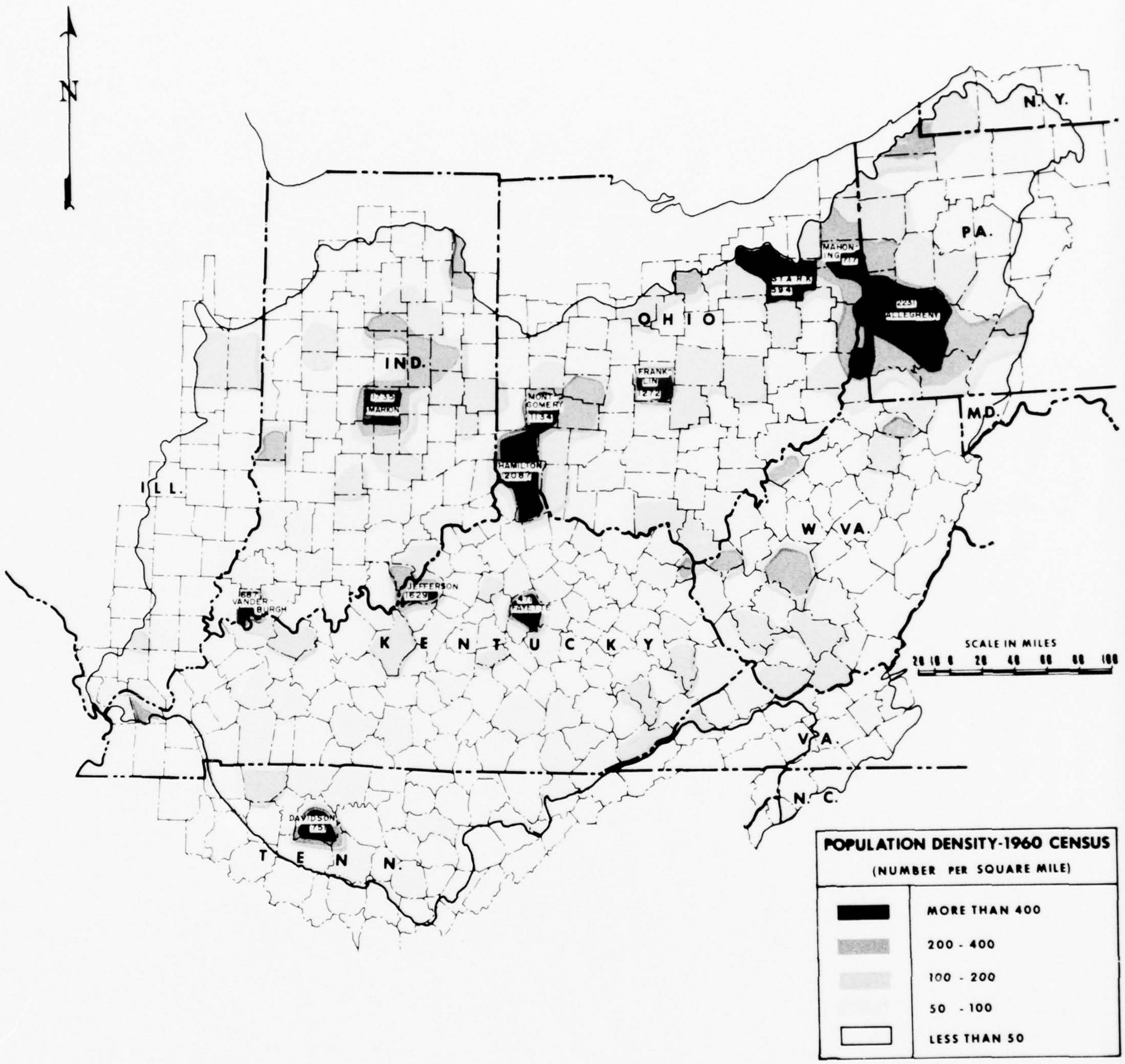
Projections of economic activity assumed an expanding national economy, a high level of employment, no major depressions or wars, a continuation of the current relative needs of civilian economy and national defense, and the timely availability in the Ohio Basin of land and water adequate in quantity and quality to support the economy.

32. Over 35 percent of the socio-economic activity in the basin takes place in the economic subareas along the Ohio River and the Pittsburgh subarea at the head of the river, which contain about 18 percent of the basin area. Because of its importance to the economy, this segment might well be called "the backbone" of the basin. Most of the counties making up these subareas are contiguous to the Ohio River, and the following tabulation lists their shares of the total basin economy.

	Ohio River Counties Percent of Basin Total 1960
Population, Total	34
Population, Urban	42
Employment	34
Manufacturing Output	38
Transportation, Communications, and Utility Output	40
Electric Power, Installed Capability	45

33. Large manufacturing centers throughout the basin require ample, economical, and high-quality water supplies. Where plants are located near the Ohio River or its navigable tributaries, many raw materials and bulk products are delivered on canalized waterways. Concentration of industry with its accompanying urban development creates a great demand for electrical energy, transportation, and recreation and often results in flood protection, water supply, and waste treatment problems.

Steel mills at Pittsburgh and Johnstown, Pa., Wheeling, W. Va., Ashland, Ky., and Middletown, Ohio, are some of the most important in the



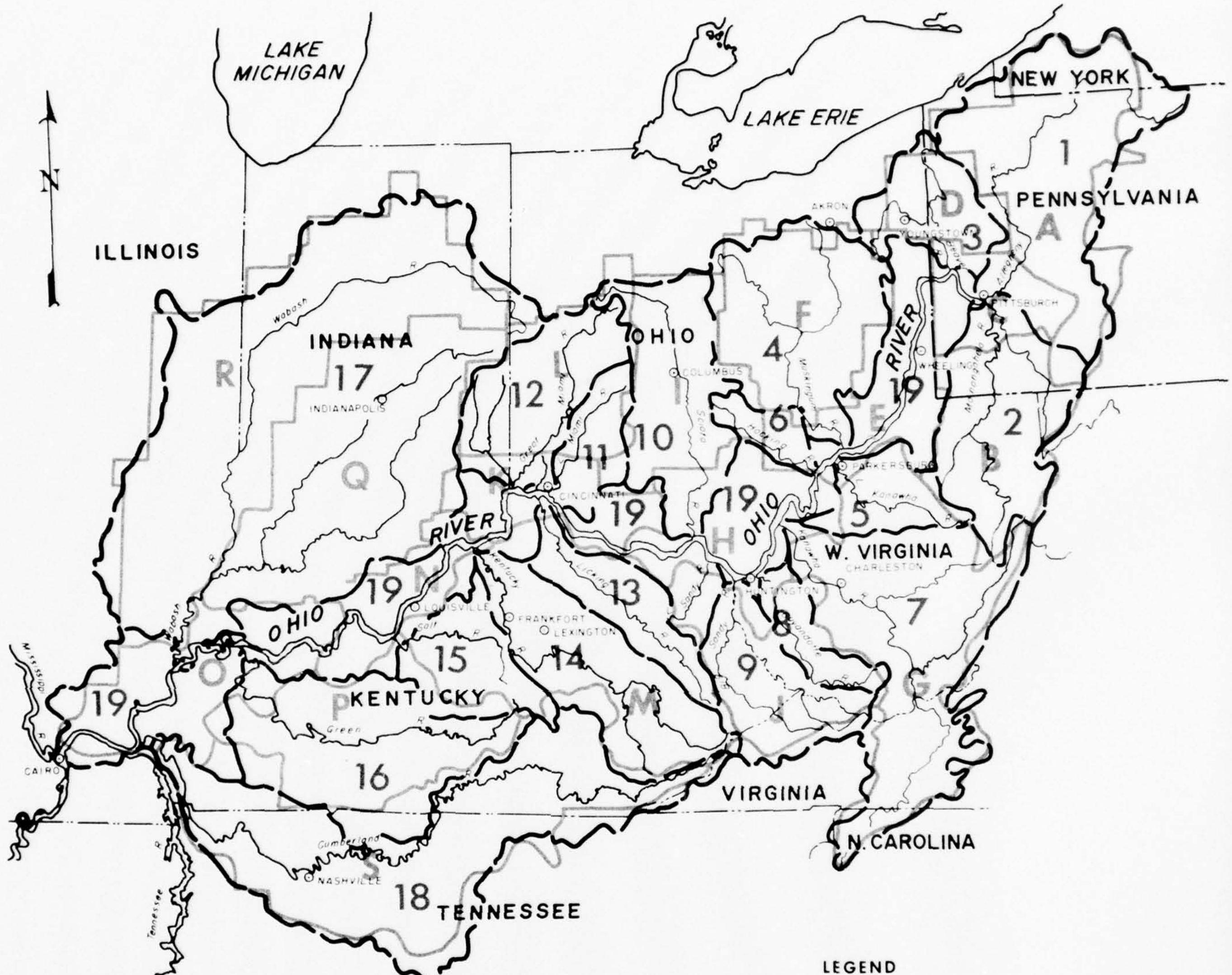
NOTE: Population density shown by counties.
Names and numbers are highest density areas.

OHIO RIVER BASIN COMPREHENSIVE SURVEY

POPULATION DENSITY

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE 4



LEGEND

▬ ▬ ▬	HYDROLOGIC SUBAREA
— · —	STATE BOUNDARY
○	CITY
———	ECONOMIC SUBAREA BOUNDARY

HYDROLOGIC SUBAREAS

1. ALLEGHENY
2. MONONGAHELA
3. BEAVER RIVER
4. MUSKINGUM
5. LITTLE KANAWHA
6. HOCKING
7. KANAWHA
8. GUYANDOTTE
9. BIG SANDY
10. SCIOTO
11. LITTLE MIAMI
12. GREAT MIAMI
13. LICKING
14. KENTUCKY
15. SALT
16. GREEN
17. WABASH
18. CUMBERLAND
19. OHIO RIVER MINOR TRIBUTARIES AND OHIO RIVER MAINSTEM

ECONOMIC SUBAREAS

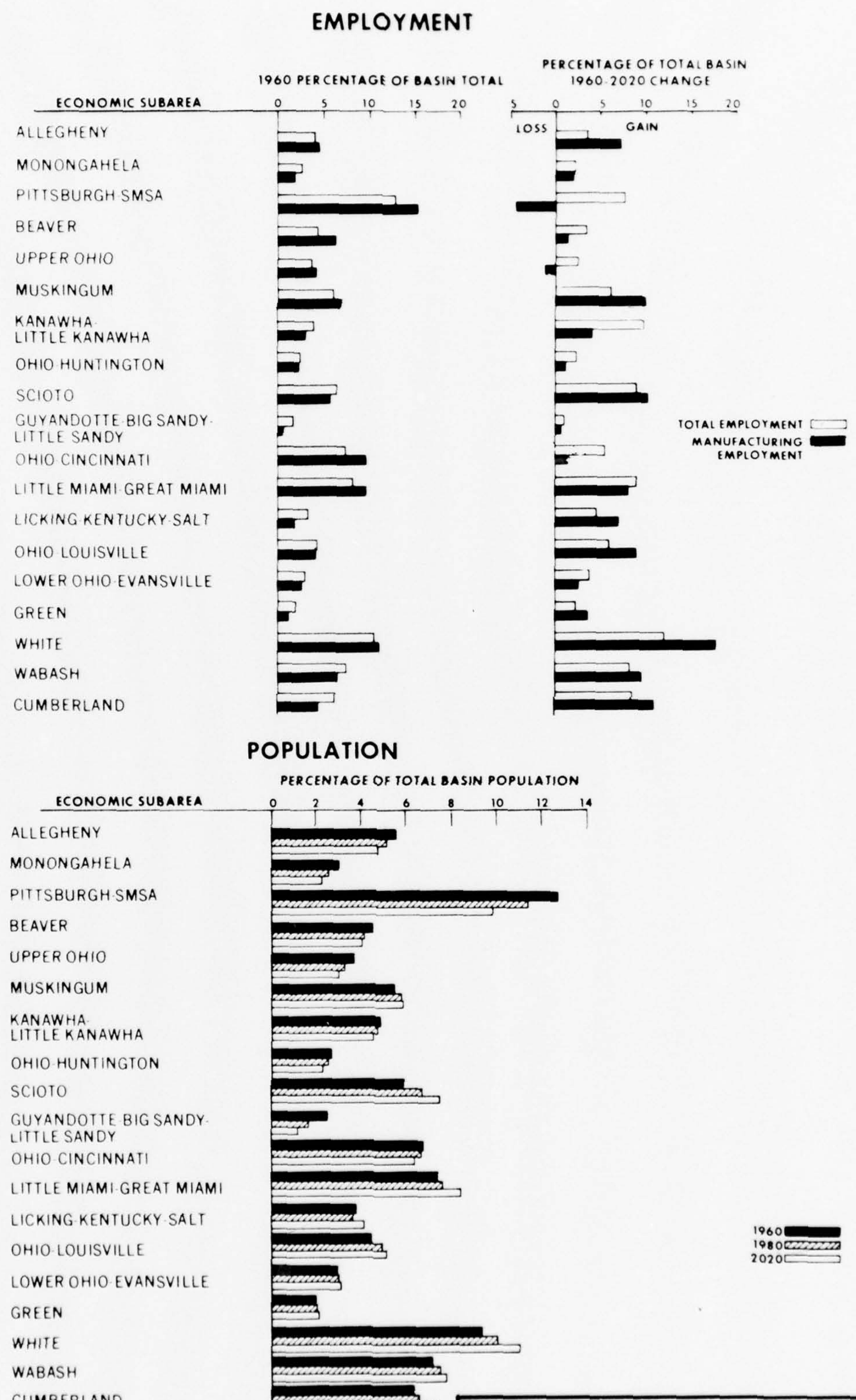
A. ALLEGHENY
B. MONONGAHELA
C. PITTSBURGH SMSA
D. BEAVER
E. UPPER OHIO
F. MUSKINGUM
G. KANAWHA-LITTLE KANAWHA
H. OHIO-HUNTINGTON
I. SCIOTO
J. GUYANDOTTE-BIG SANDY-LITTLE SANDY
K. OHIO-CINCINNATI
L. LITTLE MIAMI-GREAT MIAMI
M. LICKING-KENTUCKY-SALT
N. OHIO-LOUISVILLE
O. LOWER OHIO-EVANSVILLE
P. GREEN
Q. WHITE
R. WABASH
S. CUMBERLAND

OHIO RIVER BASIN COMPREHENSIVE SURVEY

ECONOMIC AND HYDROLOGIC SUBAREAS

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE 5

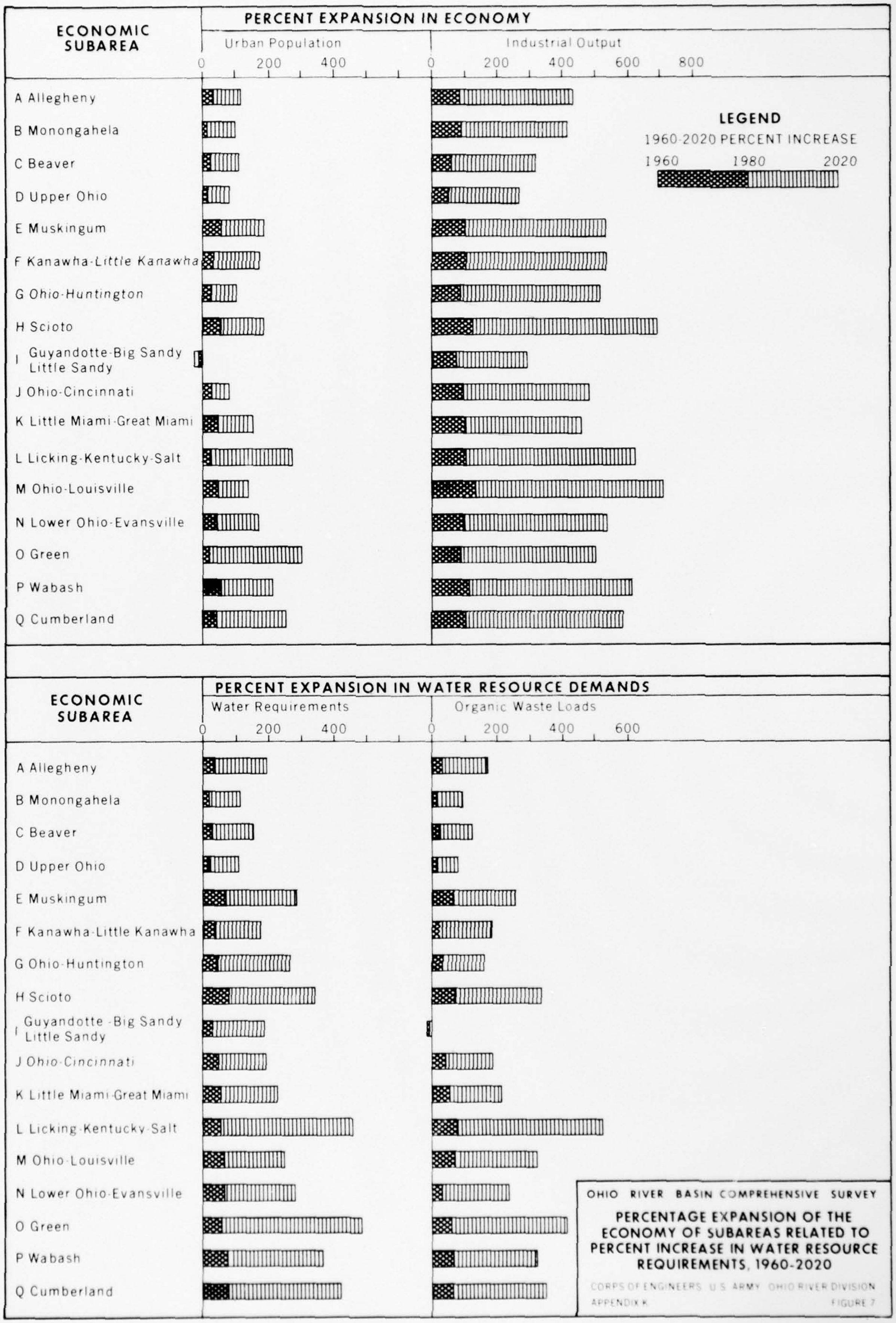


OHIO RIVER BASIN COMPREHENSIVE SURVEY

SUBAREA EMPLOYMENT AND POPULATION INTERRELATIONSHIPS

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE 6



OHIO RIVER BASIN COMPREHENSIVE SURVEY

PERCENTAGE EXPANSION OF THE ECONOMY OF SUBAREAS RELATED TO PERCENT INCREASE IN WATER RESOURCE REQUIREMENTS, 1960-2020

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE 7

Nation. Water supply requirements and problems associated with stream pollution are an important concern of the industry at these locations. The Kanawha Valley is the site of a major chemicals-producing center, and riverside plants in the vicinity of Charleston, W. Va., create unusual pollution problems. In-plant reduction in wasteloads and special waste treatment processes are currently practiced; but additional techniques and facilities are required now, and still more will be needed as productivity increases.

34. Although the Ohio Basin is most often thought of as an industrial area, agriculture is still a principal pursuit. About one-third of the area is under cultivation and contains some of the most productive agricultural lands in the Nation, particularly in the Corn Belt Region, which extends through central Illinois and Indiana into Ohio, and the Bluegrass Region in Kentucky. On the rough land bordering the Ohio River and to the south where soils are generally less fertile and erosion more pronounced, farms are predominantly small. Land use, by economic subareas, is given in table 2. Agricultural productivity is expected to increase rapidly and will be aided materially by solution of problems associated primarily with water availability, land treatment and management, and erosion control.

35. The basin's minerals production is significant on a worldwide scale and represents 12 percent of the total U.S. mining output value. Fossil fuels constitute the basin's major mineral resources. Bituminous coal, the basin's leading mineral product, accounts for over 75 percent of all U.S. production. Coal-bearing strata occur in southwestern Indiana, eastern Illinois, western and eastern Kentucky, western Maryland, eastern Ohio, western Pennsylvania, Tennessee, Virginia, and West Virginia. Annual production in 1964 was 379 million tons valued at $1.68 billion. Petroleum and natural gas wells in Pennsylvania, Ohio, Indiana, Illinois, and Kentucky produced 86 million barrels of oil and 377 billion cubic feet of gas valued at $350 million. Drainage from mines and brine discharge from oil wells cause stream pollution problems. Coal mining, particularly stripping operations, result in movement of large volumes of earth which creates problems related to land erosion, sedimentation, and pollution of streams.

There are abundant supplies of salt, fire clay, glass sand, gypsum, and limestone throughout the basin. Important deposits of fluorspar occur in western Kentucky and southern Illinois. Details on mineral resources and mining are given in attachment B to this appendix.

36. Forests and their products are of major importance to the basin economy. The Ohio Basin produces 20 to 25 percent of the Nation's hardwood lumber. Fifty-nine percent of the commercial forest growing stock is in sawtimber, the bulk being used for lumber, veneer, plywood, paper, and other products. The forests also provide wildlife habitat and hunting opportunity.

PLANNING ENVIRONMENT

37. Forty-nine percent of the Ohio Basin is in the region designated as Appalachia. This includes all of the Ohio Basin study area located in Maryland, New York, North Carolina, Pennsylvania, and West Virginia, and parts of the Ohio Basin areas in Kentucky, Ohio, Tennessee, and Virginia. The Appalachian portion of the study area is lagging in economic growth. In 1960, only 49 percent of the inhabitants were urban dwellers. Farms are generally small and hardly sufficient to support the occupants. In some remote counties, as many as 75 percent of the families had incomes of less than $3,000 in 1960. The region is rugged and forested, of great scenic beauty, and ideal for recreation sites. Access by new highways and construction of reservoirs can be important in the development of the recreation potential. Solution of acid mine drainage problems in Appalachia would increase fish habitat and recreational use of the streams.

LAW AND POLICY

38. The guidelines and constraints applicable to planning accomplishment are established by prevailing law and policy. A general orientation is therefore desirable on existing law and policy regarding basic authorities and responsibilities of the various agencies which establish the governmental atmosphere under which planning studies, plan formulation, and development programs have been accomplished.

39. Early law and related policy dealt almost exclusively with development and regulatory aspects of the use of resources. Recent legislation and attendant policy have been concerned with defining more specifically the fields of responsibility; relationships of Federal, State, and other non-Federal entities; and the coordination and cooperation required of these entities for accomplishing water resource planning and development objectives in a unified and comprehensive manner.

40. States and Commonwealths. - Despite the continuing trend toward acceptance of a greater degree of responsibility at the Federal level, many aspects of management of water and related land resources are still regarded as primarily, or even exclusively, non-Federal. States, political subdivisions, and private interests have the primary responsibilities in waste treatment, pollution abatement, public water systems and treatment, electric power developments, watershed protection and management, recreation, fishing, hunting, and flood plain zoning.

Ohio Basin States adhere to the riparian concept of surface water rights; but this basic doctrine has been and is still being modified in varying degrees from State to State. Many have adopted a "reasonable use" limitation. Kentucky's newly enacted water statute declares water occurring in any stream, lake, ground water, subterranean water, or other body which may be applied to any useful and beneficial purpose, to be a natural

resource and public water of the Commonwealth, subject to control or regulation for the public welfare. With certain exceptions, withdrawal of water from such a source will, henceforth, require a permit from the Department of Natural Resources.

The powers and duties of State agencies, municipalities, counties, townships, special-purpose districts and private interests have their origin in State constitutions and statutes. Laws and policies governing water resource development and use, as well as the governmental and administrative structure for accomplishing the planning and coordination of water resource activities, vary among the Ohio Basin States. Some States rely on the rules of common law to deal with the problems; others, on statutory authority and law. In the individual States, authority and responsibility for developing the resources and regulating their use are centralized to varying degrees. Some States operate in strict observance of the home rule concept. Several are at the other extreme, with the administration of planning, management, and coordination functions centralized at the State level. These variances are reflected in different organizational alignment, administrative procedures, and staffing for planning and planning coordination within house and with outside elements.

Also significant is the apparent trend toward a greater centralization of planning and administration and an improved coordination within the States. Since the Ohio River Basin study began, West Virginia and Indiana have each created a Department of Natural Resources. Illinois created a Board of Economic Development for statewide planning and then converted it to a Department of Business and Economic Development. In planning for water resources development, the director of the department is assisted by a technical advisory committee made up of the heads of agencies responsible for development and management of water and related land resources. New York's Water Resources Commission, a planning and policy-making body, is somewhat similarly constituted. Recent legislation adopted by Ohio strengthens its water resource planning, development, and management programs.

Some States have been more active than others in planning and developing programs for the management of water and related land resources. Lesser activity may be due in part to State law and policy, and also to differences in population density, economic development, and financial resources of the various areas.

"Appendix J: State Laws, Policies, and Programs" presents the framework of the laws, policies, and programs in the different basin States and contributes substantially to an understanding of State and local views toward planning for and execution of water and related land resources development.

In addition to individual State laws, an interstate compact creating the Ohio River Valley Water Sanitation Commission was ratified by eight States to deal with regional water quality problems. Other existing interstate compacts are listed in Appendix J.

41. Federal law. - At Federal level, departmental and agency authorities and relative responsibilities in the water resources field stem from the various River and Harbor Acts; Flood Control Acts; Fish and Wildife Acts; Watershed Protection and Flood Prevention Acts; Federal Power Act; acts pertaining to recreation; those concerned with water supply, pollution control, and water quality; and the Water Resources Planning Act of 1965, which broadens and extends planning responsibilities and authorities contained in prior acts. The acts applicable to departments and agencies participating in the Ohio River Basin Comprehensive Survey are referenced, where appropriate, in the various appendices and attachments to the report.

Policy for guidance of the planning and coordination activities of Federal agencies are contained in Senate Document No. 97, approved by the President and endorsed by the Senate in May 1962. The document presents unified policies, standards, and procedures to be applied in the formulation, evaluation, and revision of plans for use and development of water and related land resources.

Senate Document No. 97 is an expression of a broadened philosophy and expanded viewpoint in national planning objectives and policy. Section III: Planning Policies and Procedures provided that "All viewpoints - national, regional, State, and local - shall be fully considered and taken into account in planning resource use and development. Regional, State, and local objectives shall be considered and evaluated within a framework of national public objectives and * * * needs. * * * Planning by Federal agencies shall * * * be carried out in close cooperation with appropriate regional, State, or local planning and development and conservation agencies, to the end that regional, State, and local objectives may be accomplished to the greatest extent consistent with national objectives. When a proposed resource use or development affects the interest and responsibility of non-Federal public bodies, those bodies shall be furnished information necessary to permit them to evaluate the physical, economic, and social effects. Their views shall be sought, considered in preparation of reports and included in the final reports submitted to the President and the Congress or other approving authority." Thus, all interests, Federal, State, and other non-Federal entities, were enjoined to establish between and among themselves a unification of purpose and a high degree of coordination and cooperation in planning for future water resource development and use. To assist in accomplishing these purposes and help resolve any differences that might arise during the Ohio Basin study, a coordinating committee of Federal and State delegates was formed. Details are given in "Appendix A: History of Study".

42. Guidelines for framework studies. - The concept of framework or type I planning studies, formalized in the Water Resources Council's "Guidelines for Framework Studies," was conceived and promulgated for application in the national program for comprehensive river basin planning.

PLANNING ENVIRONMENT

The full text of the guidelines, from which pertinent excerpts are stated below, is contained in Appendix A.

The guidelines define the *general nature* of study requirements and limitations. They state that "Framework studies will be preliminary or reconnaissance-type investigations intended to (a) provide broad-scaled analyses of water and related land resource problems; and (b) furnish general appraisals of the probable nature, extent, and timing of measures for their solution." Further guidance given is that "framework plans will be based on initial planning steps using general relations, reasoned approximations, available data, and the judgment of experienced planners. While potential sites may be identified, project formulation studies will not be undertaken at any stage of framework planning."

FRAMEWORK PLANNING CONCEPTS

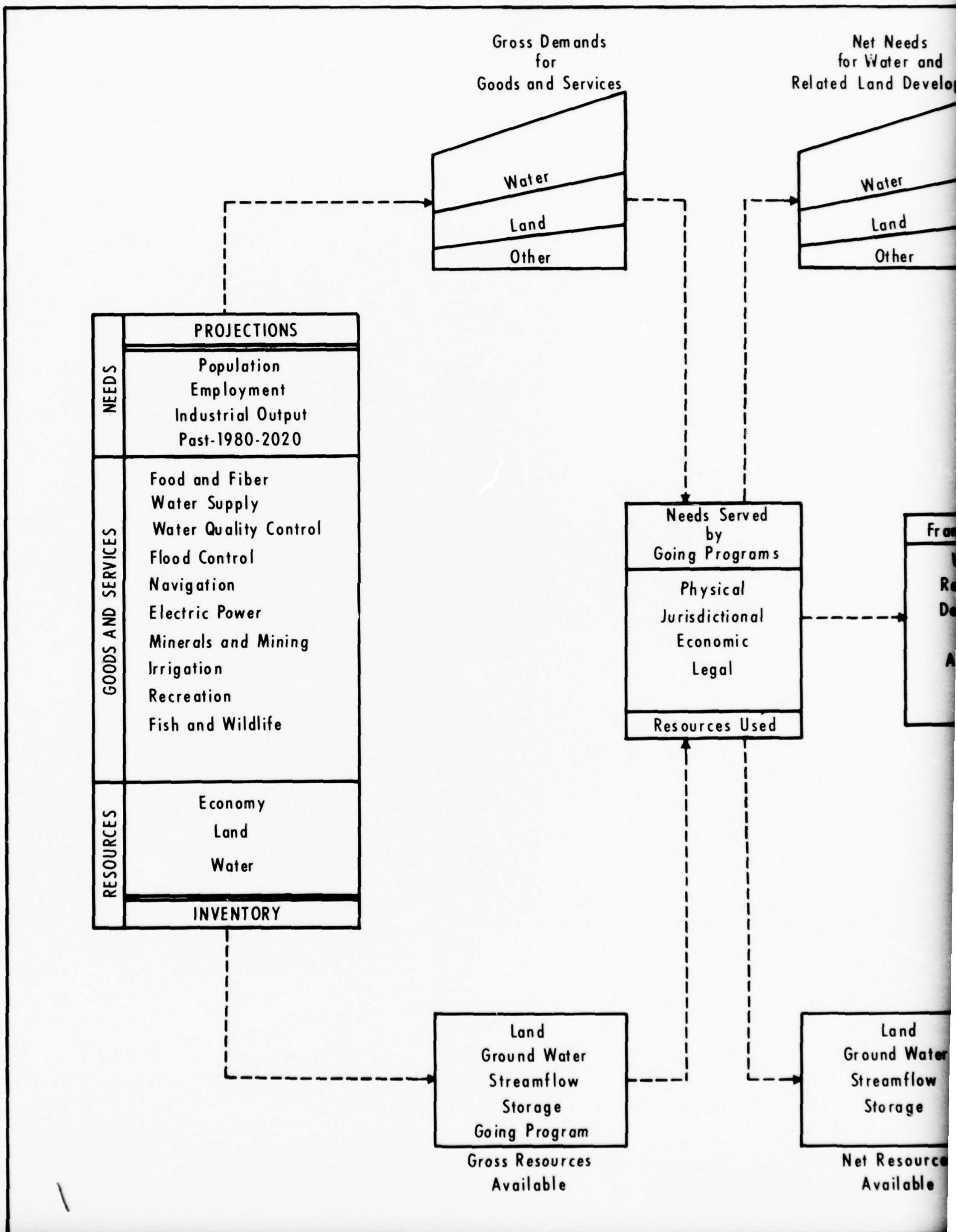
43. The provisions of Senate Document No. 97 and "Guidelines for Framework Studies" contain the policies, standards, and procedures that provided the *basic rules for formulation* of the Ohio River Basin framework plans and development programs.

44. The planning concept and process followed is relatively simple in regard to basic steps involved, yet comprehensive in terms of investigative coverage and details handled. Procedural steps under the overall framework planning concept are shown diagrammatically in figure 8. Stated in simplest terms, implementation of the planning process involved (a) determination of the gross demand on water and related land resources by the present and projected production of goods and requirements for services; (b) assessment of the effectiveness of available resources and going programs in satisfying the demands; (c) determination of net or remaining demands on water and related land and assessment of net resource availability; and finally, (d) formulation of the plan of development which would provide a guide for the best use or combination of uses of the available water and land resources in satisfying short- and long-term needs. Elements of the plan with their cost were then delineated by time periods in accord with the goals set in meeting development needs in the basin.

45. Key precepts in formulating the framework plan were as follows: (a) The framework plan would be accomplished on the premise that, as the competition for available resources increases in the future, laws and management policies would be adopted in the entire basin to implement efficient development and use of the water and related land resources in accordance with need; and (b) budgeting limitations imposed by future availability of funds and the necessity for other programs would not be a constraint on implementing the plan of development identified as being required to meet projected needs.

46. The first step in establishing water and related land resource requirements was "Appendix B: Projective Economic Study," which evaluated economic factors throughout the basin and made projections of future values. The results formed a common base for determination of gross demands in terms of products and services. The appendices by participating agencies provided basic data and analyses of the various categories of demands on water and related land resources. Net requirements were established as those remaining after deducting the capabilities of the going programs from the gross requirements. Assessments were made of present and projected gross and net resources. For purposes of reporting, numbers were rounded. Net requirements were compared with the net resources available, and potential means of satisfying unfulfilled requirements were established. These basic assessments provided a choice of alternative solutions to many problems. Section VI provides an outline of the procedures followed in formulation of the plan of development.

47. The study was coordinated with the staffs of the Federal and State agencies represented on the Coordinating Committee. It was also coordinated with the comprehensive studies for the development of water resources in Appalachia and the Wabash and Kanawha Basins. Local views were obtained through the State members of the Coordinating Committee and by participation of individuals representing various interests at Coordinating Committee meetings.


Gross Demands for Goods and Services
Water
Land
Other
Net Needs for Water and Related Land Develo
Water
Land
Other
PROJECTIONS
NEEDS
Population
Employment
Industrial Output
Past-1980-2020
GOODS AND SERVICES
Food and Fiber
Water Supply
Water Quality Control
Flood Control
Navigation
Electric Power
Minerals and Mining
Irrigation
Recreation
Fish and Wildlife
RESOURCES
Economy
Land
Water
INVENTORY
Needs Served by Going Programs
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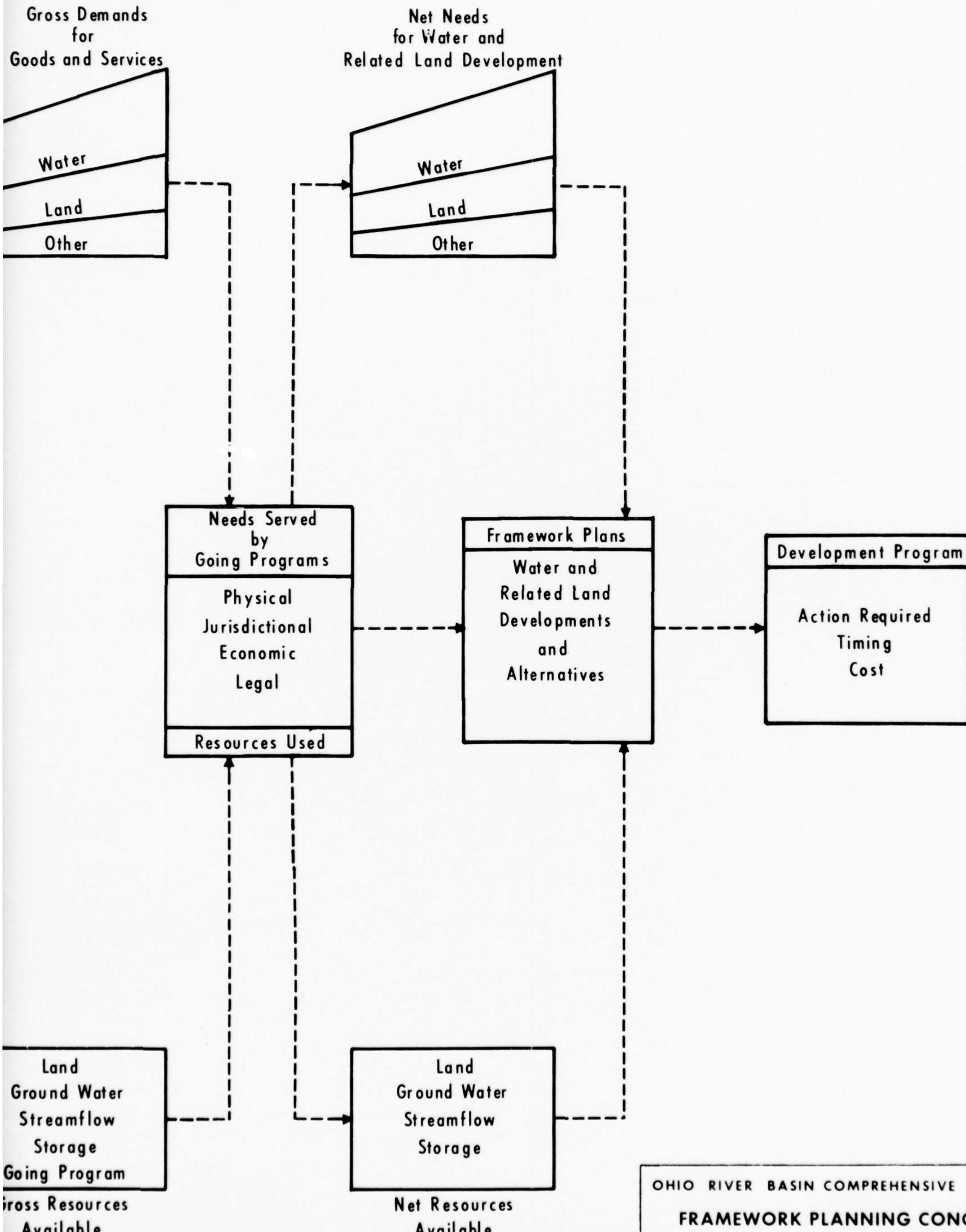


OHIO RIVER BASIN COMPREHENSIVE SURVEY

FRAMEWORK PLANNING CONCEPT

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE 8

SECTION IV

REQUIREMENTS FOR PRODUCTS AND SERVICES

GROSS REQUIREMENTS

48. The magnitude of resource development problems can be best illustrated by the fact that in the last 15 years, the Ohio Basin has produced a greater dollar value of goods and services than in all its previous history. The distribution of population and economic activity is the dominant factor influencing the demand on water and related land resources. Analysis of the changes in this distribution - past, present, and projected - when translated into needs that place a demand on utilization of the soils, minerals, forests, water, climatic, and other physiographic and geologic assets of the basin, provides basic guidance for resource development planning.

49. Present and future gross demands on water and related land resources were assessed in the appendices prepared by various agencies. "Appendix B: Projective Economic Study" was used as a basis. The dominant factors denoting economic growth are industrial employment and output trends. The following paragraphs summarize criteria, assumptions, and evaluation procedures used in translating socio-economic values into gross water and related land requirements. Pertinent basic data required for the framework planning evaluations are summarized in tables at the end of this appendix.

50. Electric power. - Water use associated with the production of electric power may be classified in two general categories: (1) The withdrawal and consumptive use of large quantities of water for cooling processes in fossil-fuel and nuclear-fired steam plants with subsequent dissipation of accumulated heat and (2) in-stream use by hydroelectric plants involving principally the regulation of flow through available hydraulic head for electric power production. The extent of water use for electric generation and its relative impact on other water uses is directly related to the magnitude and characteristics of power generation requirements, with areal distribution of use and costs of alternate sources of supply being primarily functions of type and location of power generation sources of supply.

In developing future power requirements and elements of supply, the Federal Power Commission analyzed market conditions and the many other factors influencing the magnitude and characteristics of requirements and supply. Needs of the various classes of service making up the load to be served were projected to the year 2020. The power market, selected primarily on the basis of utility physical makeup, areas served, and operating relationships with neighboring systems, is representative of the study area but does not conform exactly to basin boundaries. Generation requirements of the basin service area are summarized in the following tabulation:

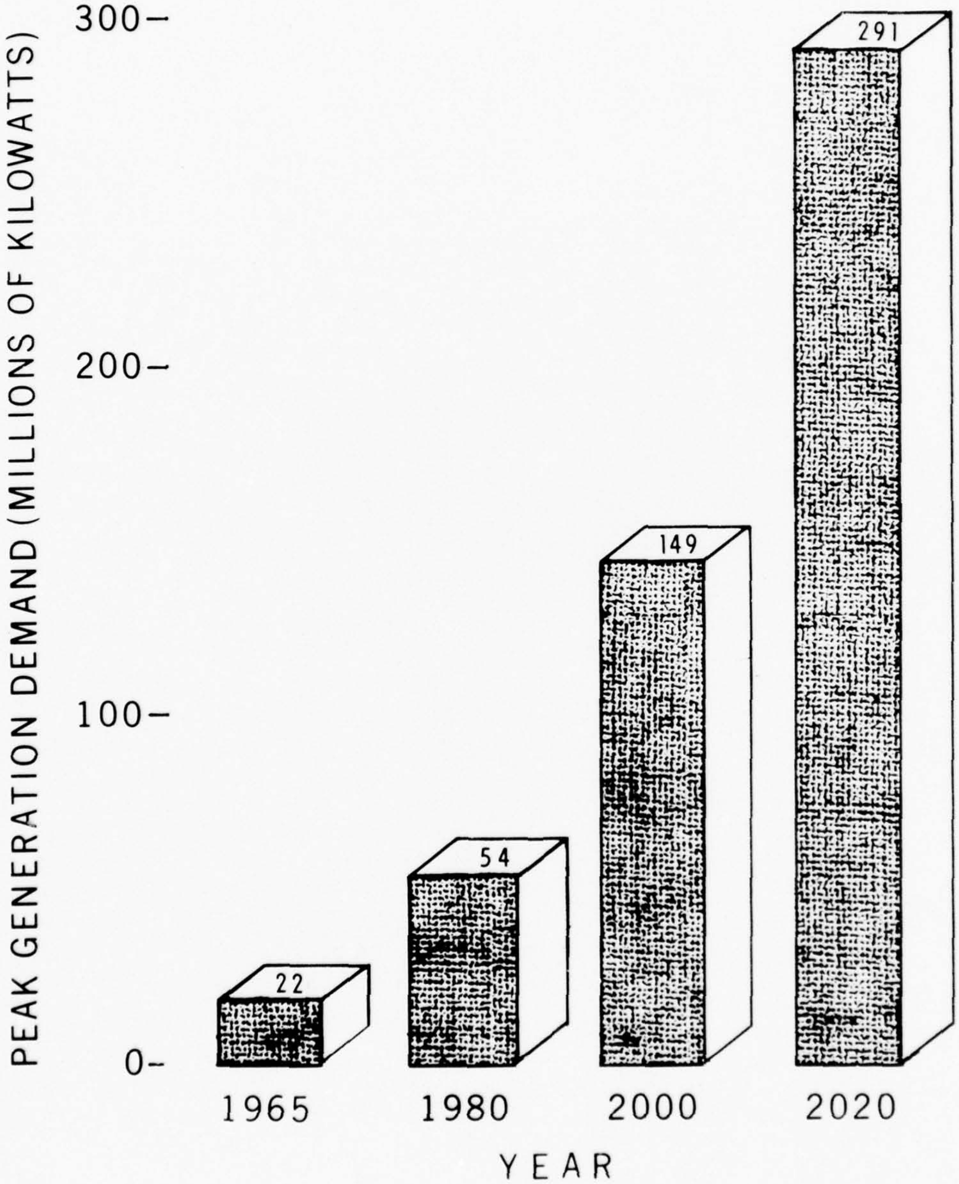
POWER REQUIREMENTS OF BASIN UTILITY MARKET

Year	Energy Requirements (Billion kw.-hr.)	Peak Demand (Million kw.)	Load Factor (Percent)
1965	132	22	68.8
1980	316	54	67.1
2000	880	149	67.4
2020	1,726	291	67.8

51. Total projected capacity installed by 2020 in the basin ranges upwards of 400 million kilowatts. This would include capacity to meet the power supply requirements of the basin market, reserves, capacity to supply other markets in the form of exports, and capacity installed by systems not in the selected market. About 80 percent of the projected total capacity is expected to be installed in large baseload generating stations with some 200 million kilowatts installed in coal-fired steam-plants located mostly in the coal regions and approximately 120 million kilowatts provided by nuclear-power plants. The remaining 80-million-kilowatt capacity would be used for peaking, standby power, and reserve needs. Of this, about 40 million kilowatts would likely be provided by gas turbines, other special purpose peaking units, and old steamplants. The residual 40 million kilowatts, or 10 percent of total capacity required, is considered a reasonable allocation of the amount of hydroelectric capacity to be provided by 2020. About 85 percent of the hydroelectric installation would be pumped storage, and the remaining 15 percent, conventional plants developed in conjunction with multiple-purpose reservoirs and navigation projects. Figure 9 shows projected electric power gross peak demands. See "Appendix I: Electric Power Resources and Requirements" for further details relating to power production.

52. Cooling water requirements and potential heat pollution problems associated with production of power from thermal plants are covered elsewhere in sections dealing with water supply and water quality.

53. Water withdrawal requirements. - Municipal and industrial water requirements, except those for mining and electric power generation cooling, were assessed by the Federal Water Pollution Control Administration (FWFCA) and the Public Health Service (PHS). For purpose of studying and projecting water requirements, the basin's 19 economic subareas were subdivided into 61 areas. Per-capita-use figures previously published for various-size cities were modified in accord with more recent data collected by State agencies and applied to the population projections. It is estimated that 70 gallons per capita per day (g.p.c.d.) are needed for domestic and commercial use. Cities of 50,000 to 100,000 population use approximately 135 g.p.c.d. including domestic, commercial, industrial, and other uses within these cities. Future use is projected to increase depending on type of activity and leveling off at a maximum of about 150 g.p.c.d.



OHIO RIVER BASIN COMPREHENSIVE SURVEY

ELECTRIC POWER
GROSS PEAK DEMANDS

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE 9

REQUIREMENTS FOR PRODUCTS AND SERVICES

Industrial water requirements not within the municipal sector were assessed in terms of daily use per employee for each type of industry. Base year industrial water use was obtained by tabulating water use of the manufacturing industries by Standard Industrial Classification (SIC) as given in the report "1963 Census of Manufactures: Water Use in Manufacturing." They were derived for each county and then divided by employment to obtain water requirements per employee. More specific information obtained from industry was used where available. Future employee water use was modified by expected changes in technology and increased productivity. Water needed in the future per unit output is expected to decrease from amounts currently used. Base year (1960) and projected gross demands for municipal and industrial water supply, by subbasins, are summarized in table 5. Consumptive use was estimated to be 10 percent of total withdrawal for municipal systems and 2 percent for industry. Details on water use and the basis for projections are given in "Appendix D: Water Supply and Water Pollution Control." Water used in mining operations is discussed in attachment B to this appendix.

54. Water requirements for rural communities, for irrigation, and for domestic and livestock use on farms were determined by the Department of Agriculture for each subbasin. Subarea summary data are given in tables 6 and 7. Table 8 provides summary data, by subbasins, on economic potentials of irrigation. Details are given in "Appendix F: Agriculture." Irrigation water requirements, by time periods, were derived from agricultural economic studies on demands for food and fiber with reference to areas which have soil types suitable for supplementary irrigation. It was estimated that an average of 6 to 7 inches of annual supplemental water could be required by 2020 over the irrigated area. The period of primary need is from July through August. In dry years, the amount may be as high as 10 inches. Consumptive use is estimated to be 100 percent of the total withdrawals since there is little return flow to streams.

55. The determination of annual demands for thermal electric power cooling water was based on power production and power plant cooling data furnished by the Federal Power Commission. "Appendix I: Electric Power Resources and Requirements" gives pertinent details.

Cooling water requirements for thermal electric power production are based on water use per kilowatt of plant capacity and vary with the type of cooling units, plant efficiency, annual capacity factor, and the permissible rise in temperature of the body of water which receives the used cooling water. For plants utilizing once-through cooling, a withdrawal of 1.4 cubic feet per second (0.9 million gallons per day) per 1,000 kilowatts of plant capacity is needed for a temperature rise of 13° F. in the condenser water. Consumptive water losses per 1,000 kilowatts amount to about 0.01 c.f.s. for once-through systems, 0.015 c.f.s. for cooling ponds, and 0.02 c.f.s. for cooling towers. Cooling water requirements for nuclear plants are approximately 30 percent higher than for fossil-fuel plants.

REQUIREMENTS FOR PRODUCTS AND SERVICES

For purposes of projections, it was assumed that about 50 of 75 million kilowatts in plants presently completed or planned for completion by 1980 would use once-through cooling. It is recognized, however, that water quality criteria recently adopted by the States with respect to stream temperatures may require supplemental cooling. The remaining 25 million kilowatts would use water impoundments or evaporative cooling towers. Beyond 1980 it is anticipated that thermal pollution problems associated with once-through cooling will become critical throughout the basin; therefore, new water requirements after 1980 are based on use of primarily the evaporative cooling method.

Cooling water requirements to be met in each of the subbasins through 1980, were determined on the basis of generating capacity projected to be installed in each subbasin. Total cooling water requirements after 1980 were determined for the study area and then prorated to each subbasin on the basis of the 1980 ratio of subbasin to total basin installed capacity.

Gross water requirements for each of the general categories of demand are summarized below in terms of average withdrawals:

GROSS WATER SUPPLY DEMANDS - AVERAGE WITHDRAWALS
(Millions of Gallons Per Day)

Use	1965	1980	2000	2020
Municipal	1,743	2,305	3,292	4,777
Manufacturing Industries	9,811	11,730	16,065	23,480
Electric Power Cooling	19,200	29,000	46,000	63,000
Mining	289	511	974	1,894
Rural, Nonfarm Domestic	587	673	794	934
Livestock	116	129	194	258
Farm Domestic	46	39	37	36
Irrigation	46	102	352	682
Total	31,838	44,489	67,708	95,061

REQUIREMENTS FOR PRODUCTS AND SERVICES

Consumptive use losses included in gross demand totals are set forth in the following tabulation:

AVERAGE CONSUMPTIVE USE
(Millions of Gallons Per Day)

Use	1965	1980	2000	2020
Municipal	174	231	329	478
Manufacturing Industries	196	235	321	470
Electric Power Cooling	158	356	705	1,240
Mining	53	79	133	244
Rural, Nonfarm Domestic	391	449	530	623
Livestock	116	129	194	258
Farm Domestic	46	39	37	36
Irrigation	46	102	352	682
Total	1,180	1,620	2,601	4,031

Gross water demands and increments of consumptive use are shown graphically in figure 10.

56. Water quality control. - In deriving water quality control gross needs, the Federal Water Pollution Control Administration (FWPCA) assumed that all wastes have been given secondary treatment or equivalent reduction before discharge to the stream. An equivalent of 0.25 pounds of ultimate biochemical oxygen demand (BOD) per person per day, was applied to total municipal populations. Although many secondary treatment plants remove more than 85 percent of the incoming biochemical oxygen demands, this percentage represents an average efficiency for a large group of plants. Figure 11 shows the Ohio River Basin wasteloads by time periods. Table 9 gives the residual waste, in population equivalents (PE), expected to enter the streams of each subbasin from municipal and industrial waste treatment plants. The gross residual wasteloads for the study area, with 85 percent of the biochemical oxygen demand removed by sewage treatment, are summarized below:

	1965	1980	2000	2020
Millions of Population Equivalents	4.6	6.0	8.8	13.4

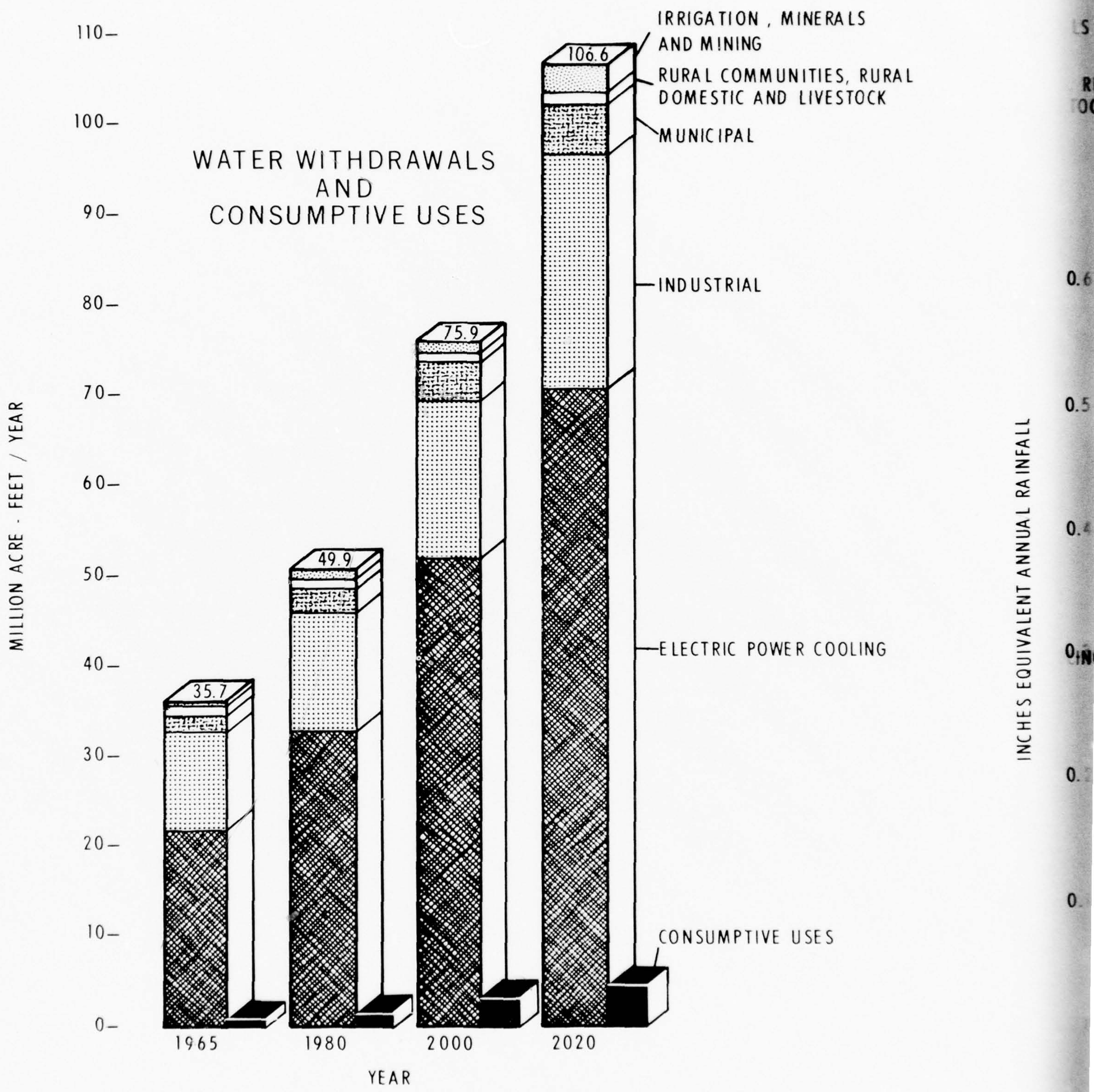
57. The requirements for organic water quality control are based on standards generally accepted in 1965. Maintenance of a level of 4 parts per million of oxygen at a temperature of 25 C. in the streams was used

as a basis to evaluate development needs. Subsequent to 1965, most States established for many streams higher standards than those used in this report. The unit of measurement for organic waste does not take into account chemical pollution that may be of equal or greater significance for some uses and in some areas. In general, however, the residual organic waste problems are most critical, and, if solved by streamflow supplementation, a satisfactory chemical quality usually will also be provided. A 7-consecutive-day low streamflow, having a recurrence interval of once in 10 years was used as a design flow to determine the assimilative capacity of the various streams. Details on the methodology used, location of problem areas, and the minimum streamflow required at selected locations in each subbasin are given in Appendix D and are summarized for each subbasin in attachment A to this appendix. Specific problems of acid drainage and chemical wastes, as well as health factors, must be considered in addition to the maintaining of a certain amount of dissolved oxygen in the streams. Detailed studies will be necessary to define the problems.

58. Mine drainage water flows into most of the streams in the coal-producing areas of the basin. Nine of the eleven States in the basin have significant mine drainage pollution problems. Discharge from operating and abandoned mines causes the principal problems. Figure 12 shows the areas of acid-polluted streams. The Allegheny and Monongahela Rivers and small tributaries of the upper Ohio River are major contributors. The future problem may be indicated by the fact that only 10 percent of the basin's known coal resources have been extracted, and 50 to 75 percent of the existing acid load comes from abandoned mines. In many cases, the acids in the water combine with iron precipitates to form yellow masses, causing unsightly conditions in the streams, killing fish, and damaging other aquatic life. Acid also makes water objectionable for manufacturing uses, and industrial and municipal water supplies have to be specially treated. Brine from oil wells and natural salt outcroppings also pollute streams as does runoff carrying fertilizers and pesticides from agricultural areas. Sediments are also stream pollutants, but these are considered primarily under erosion control, land treatment and management, and reservoir space provided in reservoirs for sediment.

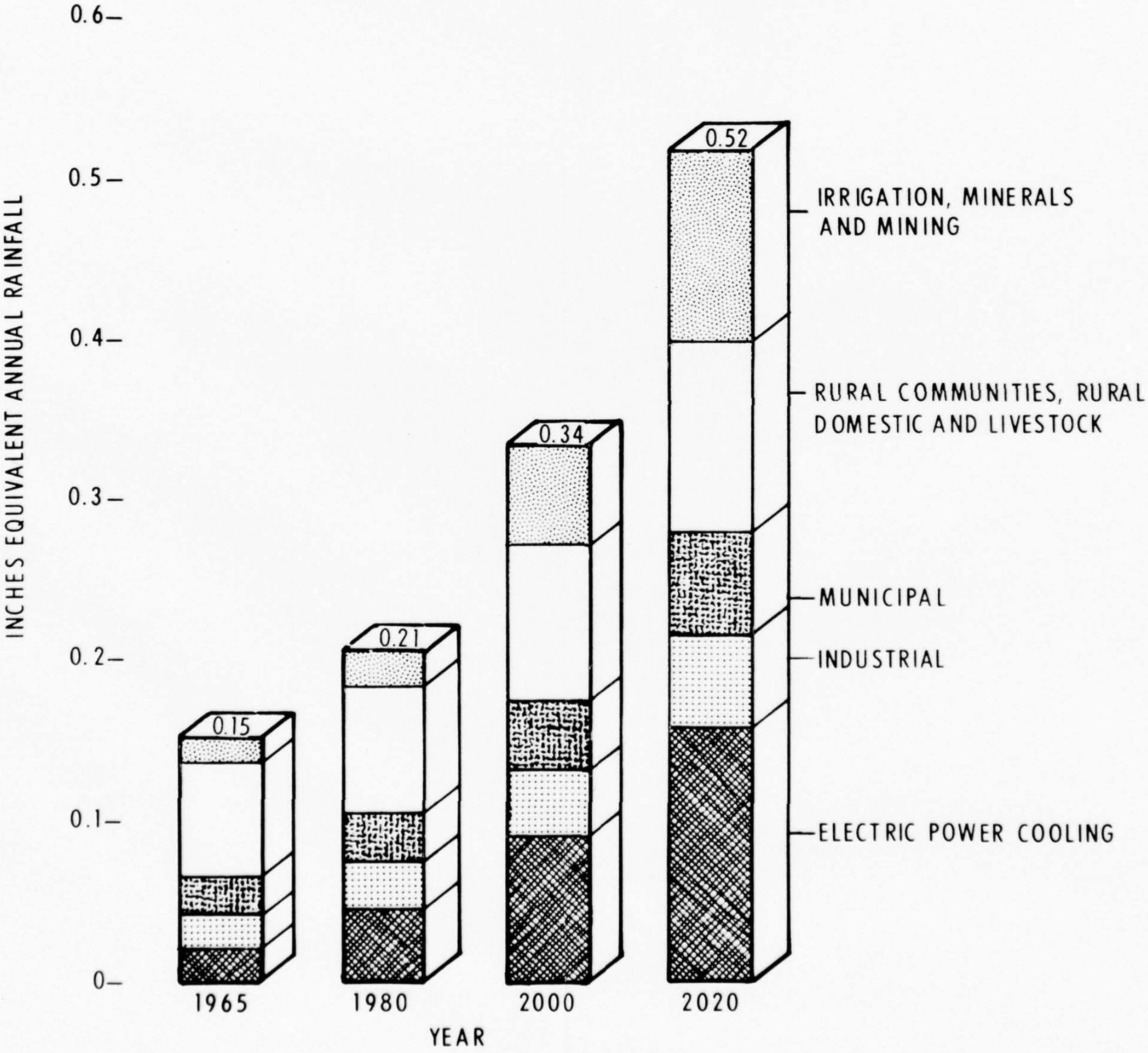
59. Flood control. - Assuming there were no flood control facilities in existence, total gross potential average annual damages based on the 1965 level of flood plain development in the Ohio River Basin are estimated by the Corps of Engineers and Soil Conservation Service to be about $350 million. Continued expansion of the economy and projected growth in the flood plains would increase these potential damages to perhaps a billion dollars annually by 2020. With protection at the level of the 1965 flood control program, however, the 1965 residual damages of $111 million are projected to only $296 million by 2020.

The 1937 flood was the most disastrous that has occurred; more than 500,000 persons were driven from their homes, and 65 lost their lives.



NOTE: 1 Million acre-feet / year is equivalent to 892 MGD

WATER CONSUMPTIVE USES

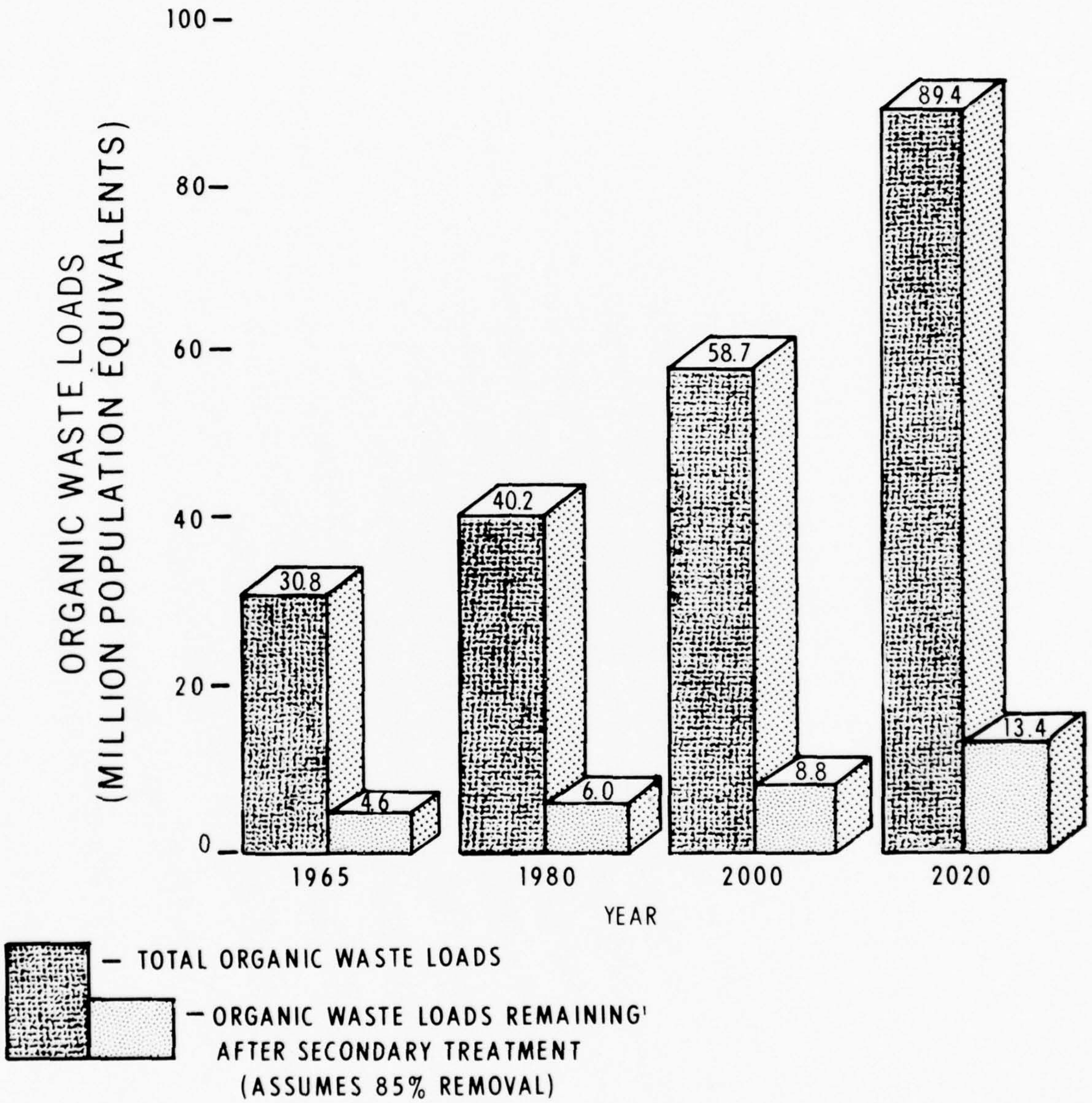


OHIO RIVER BASIN COMPREHENSIVE SURVEY

WATER SUPPLY DEMANDS

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE 10



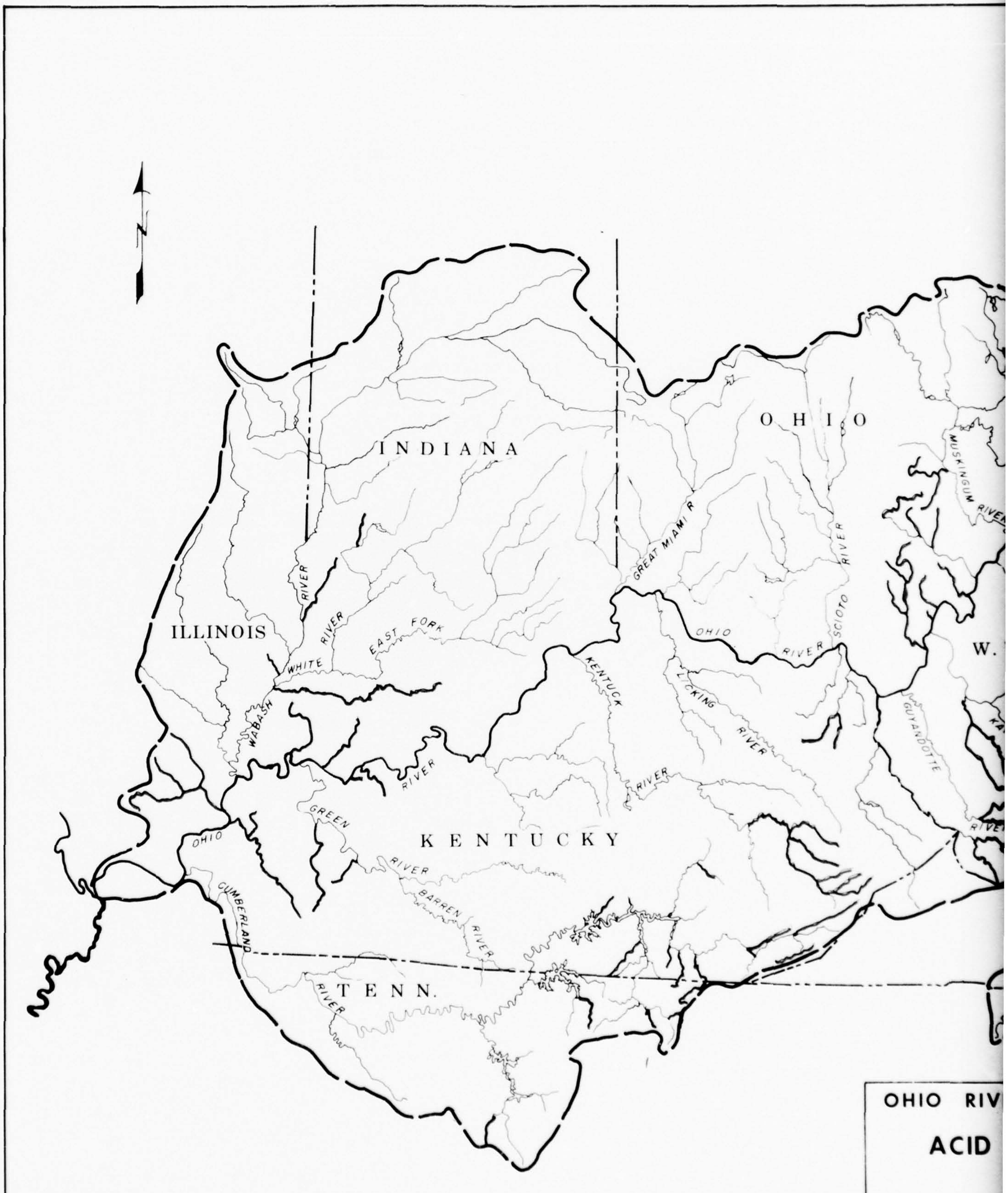
NOTE: The term "population equivalent" refers to a common denominator to which all organic wastes can be reduced. One population equivalent is equal to the amount of organic waste produced by one human being in one day.

OHIO RIVER BASIN COMPREHENSIVE SURVEY

ORGANIC WASTE LOADS

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE 11



N
INDIANA
OHIO
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W.
KENTUCKY
TENN.
WABASH
RIVER
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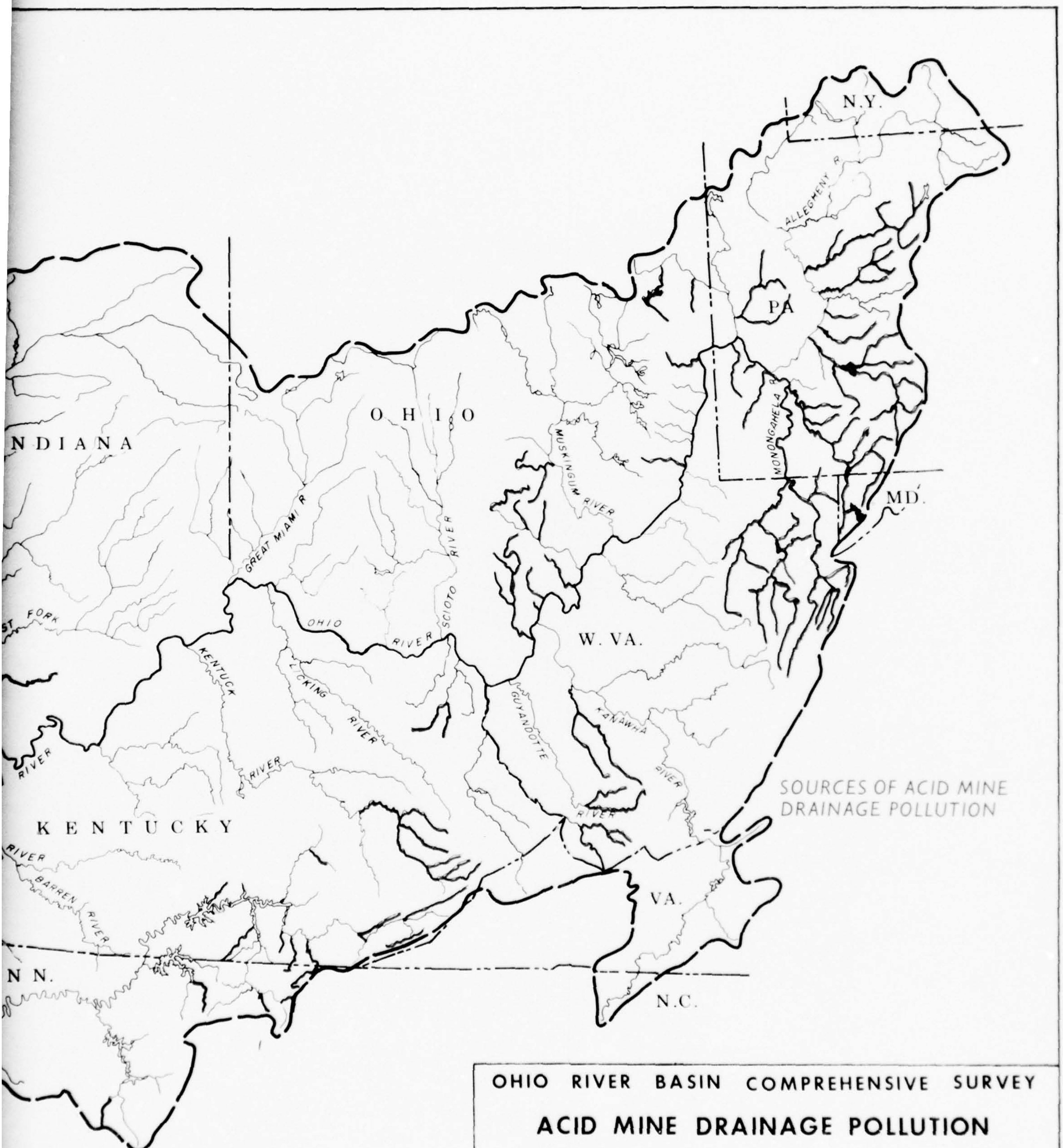


OHIO RIVER BASIN COMPREHENSIVE SURVEY

ACID MINE DRAINAGE POLLUTION

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION
APPENDIX K FIGURE 12

2

Virtually all rail, telegraph, telephone, power, and transportation facilities along the Ohio River and many tribuatries were interrupted for periods lasting from a week to a month, and business and industry were paralyzed. Damages exceeded $400 million. Larger floods could occur, and the effect would be severe, even with existing control facilities.

For purposes of this study, the basin was divided into upstream and downstream areas. Upstream areas are those with a drainage area of less than 250,000 acres where damages are primarily rural.

Future urban residential damages were based on the projected level of expenditures for housing and household goods and services and on the number of housing units estimated as likely to occupy flood-prone areas after flood plain regulation. Industrial damages were projected to grow at the rate of change in the total manufacturing output or, where at specific locations it was apparent that a particular industry mainly would be exposed to flood hazard, at the rate of change in the production levels of that industry. Projected agricultural damages, determined by the Corps of Engineers, were derived by relating present residual flood damages to indices of projected changes in acreage and yield per acre.

The procedure used by the Department of Agriculture for projecting upstream damages is based on the assumptions that (1) present flood risks will, in general, continue to be taken and (2) a continuing growth can be expected in agricultural technology. The factors used to project flood damages to crops and pasture under future conditions were derived by comparing present flood plain use and yield levels to the projected agricultural levels for each of the basin subareas. These factors were then applied to average annual losses under present development.

RESIDUAL AND PROJECTED AVERAGE ANNUAL DAMAGE
(With the 1965 Flood Control Program in Effect)

	1965	1980	2000	2020
Millions of Dollars	111	144	205	296

Of the current residual damages, $58 million are in downstream areas, and $53 million are in upstream areas. Table 10 provides summary data on subbasin flood damages. Figure 13 shows the potential flood damages. Details on flood control are given in Appendix M.

60. Navigation. - In 1965 freight traffic on the Ohio River system (excluding the Tennessee River) was about 27 billion ton-miles. By 2020, the basin's industrial output is projected to grow to nearly seven times its 1960 value and should be accompanied by a parallel increase in water transport of the bulk products of the mining, manufacturing, and petroleum industries. Navigation on the waterways in the study area is projected

to reach about 147 billion ton-miles by 2020. Figure 14 shows the 1960 and projected freight traffic on the study area waterways system. Table 14 gives the demand for water transport in the region.

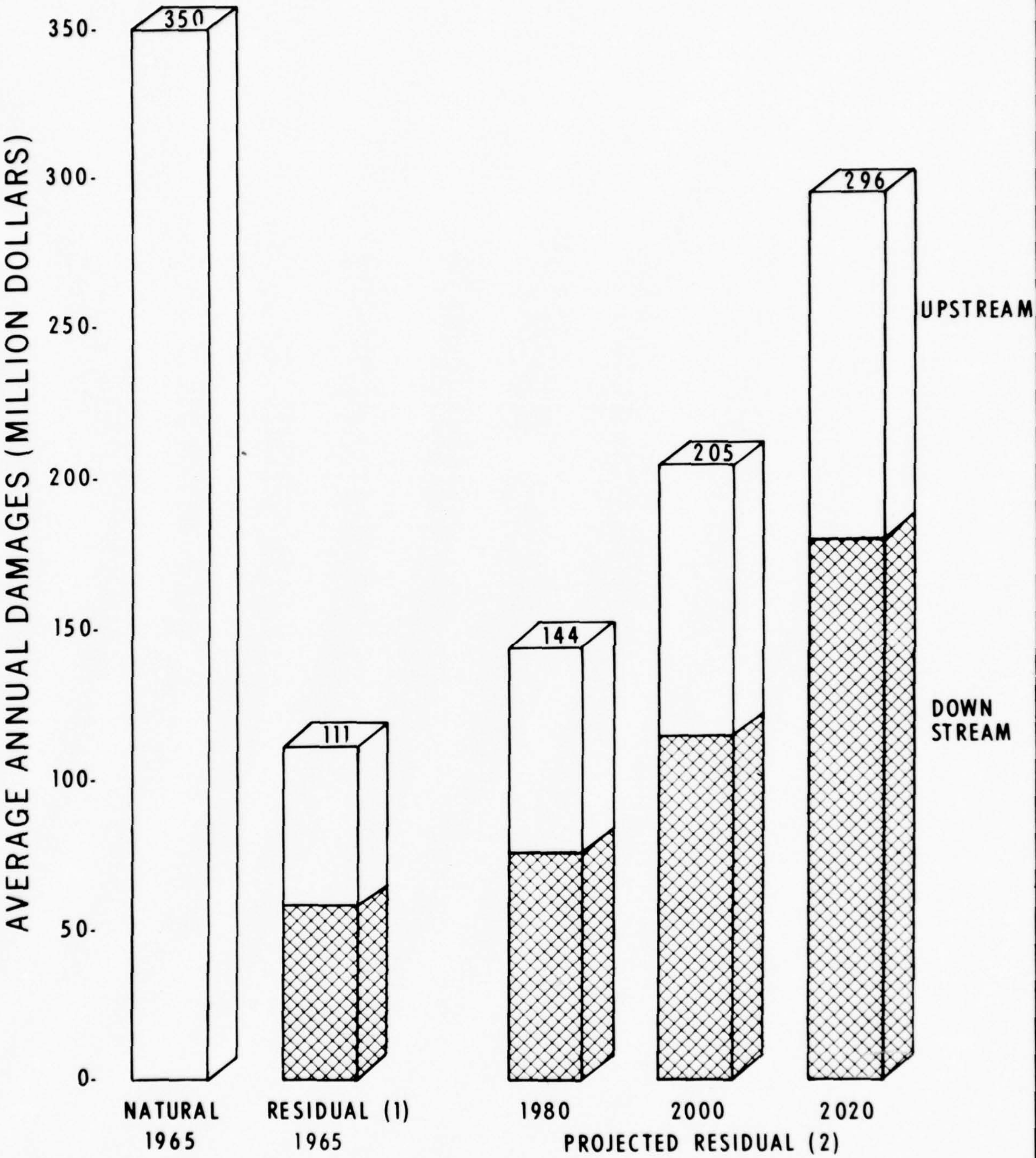
Traffic through individual Ohio River locks ranged in 1965 from 18 to 30 million tons. Lock No. 52 was the busiest on the river. By 2020, it is estimated that an annual movement approximating 155 million tons may be expected through each of several navigation structures.

61. Projections of waterborne commerce for the Ohio River and navigable tributaries were derived by relating projected indices of demands for commodities susceptible to water transport to historical area-to-area movements by water. The commodity groups considered were coal and coke; petroleum and allied products; iron and steel; chemicals and sulfur; stone, sand, and gravel; and unclassified. The following tabulation summarizes the 1965 and projected Ohio River system commerce:

	1965	1980	2000	2020
		Billion Ton-Miles		
Ohio River	23.3	42.0	76.0	127.0
Tributaries (Tennessee River omitted)	4.0	6.1	10.0	14.3
Potential New Waterways	-	1.2	4.5	6.1
Total in Study Area	27.3	49.3	90.5	147.4

62. Outdoor recreation. - In the last two decades of increased leisure time, outdoor recreation has attained a recognized status of importance in the nation's social and economic life. The demand for recreation has increased the States', local, and Federal participation in water resources development and has resulted in legislation redefining Federal responsibility for water-related recreation. Outdoor recreation as used herein includes that part of leisure-time activities, except hunting and fishing, which utilize water and related land recreational facilities. Increased life expectancy, a changing age distribution, a population shifting from rural to urban setting, income changes, and improvement of travel facilities have been important factors in its rapid growth. Approximately 58 percent of the basin's inhabitants in 1960 were urban dwellers, and it is estimated that by the year 2020, the figure will be 75 percent.

63. About half of the population prefers water-related recreation to other outdoor leisure-time activities. This share is expected to increase as new reservoirs provide greater opportunities and as new activities are developed. Improved highway systems and more rapid and economical modes of transportation enhance people's ability to travel, thus inducing a further increase in recreation demand.



NOTES

(1) RESIDUAL AVERAGE ANNUAL DAMAGES WITH THE JULY 1965 FLOOD CONTROL PROGRAM ASSUMED TO BE FULLY EFECTIVE

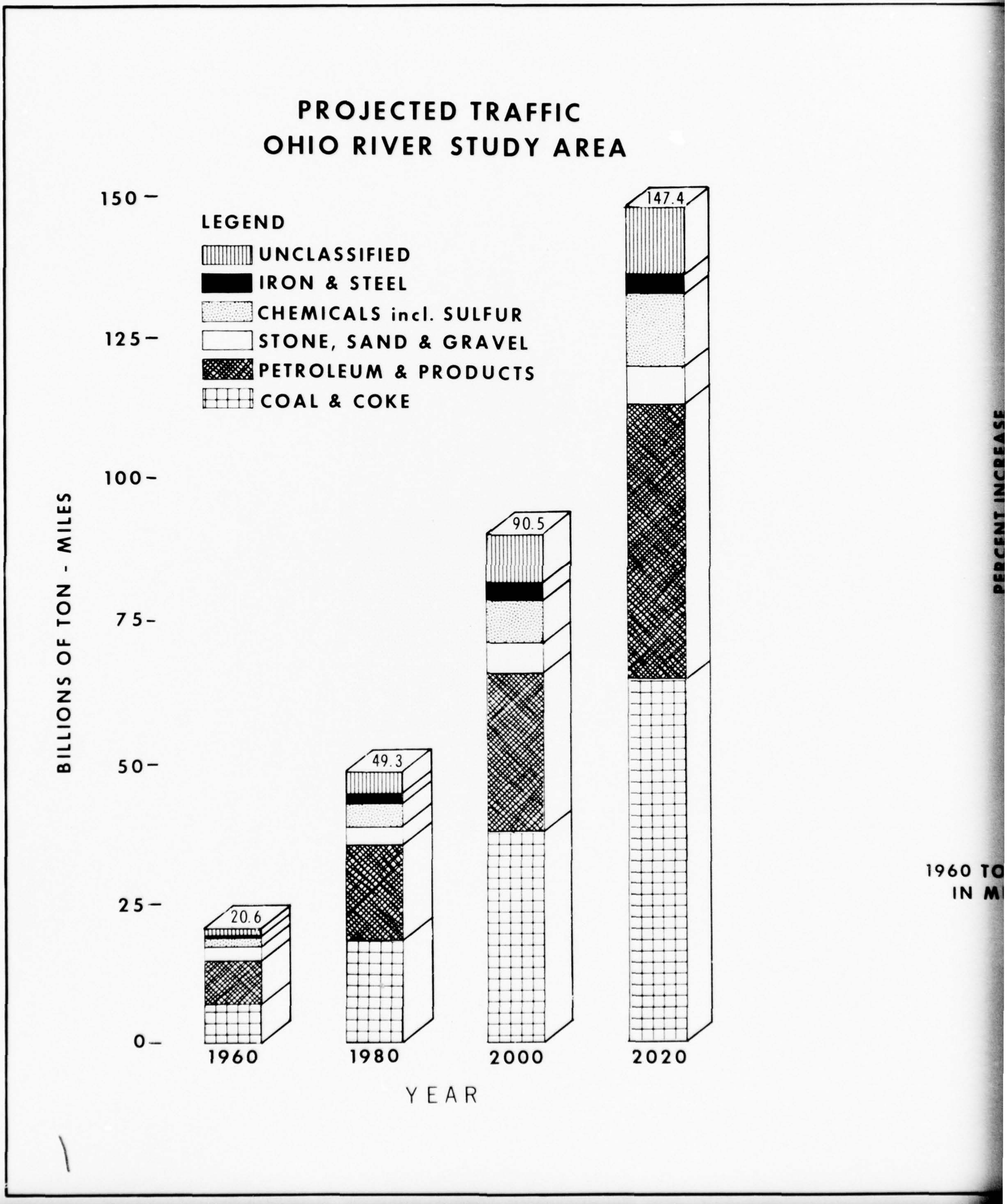
(2) ASSUMES NO ADDITIONAL FLOOD CONTROL WORKS BEYOND JULY 1965 PROGRAM

OHIO RIVER BASIN COMPREHENSIVE SURVEY

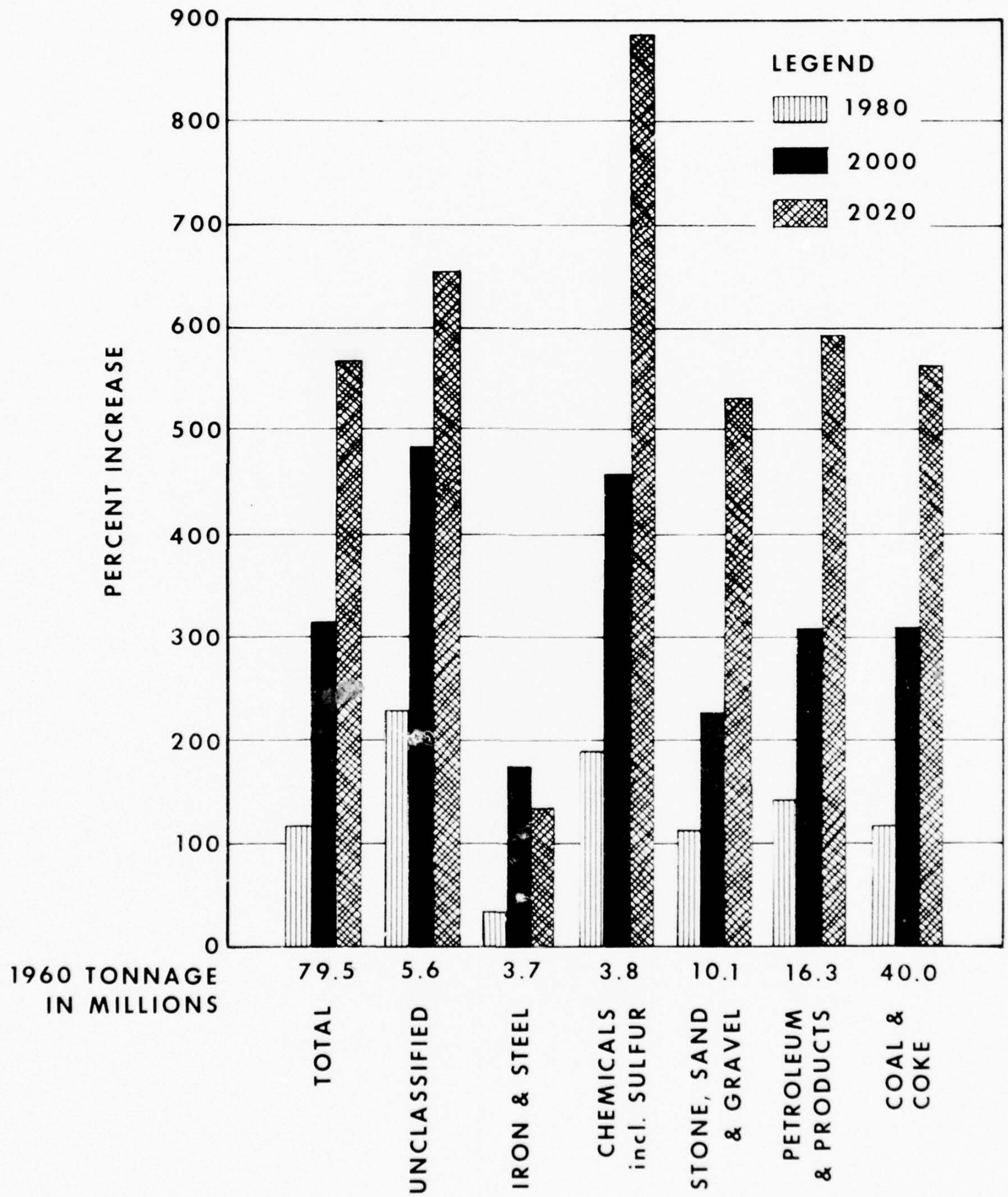
POTENTIAL FLOOD DAMAGES

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE 13


PROJECTED TRAFFIC
OHIO RIVER STUDY AREA
LEGEND
UNCLASSIFIED
IRON & STEEL
CHEMICALS incl. SULFUR
STONE, SAND & GRAVEL
PETROLEUM & PRODUCTS
COAL & COKE
BILLIONS OF TON - MILES
150
125
100
75
50
25
0
20.6
49.3
90.5
147.4
1960
1980
2000
2020
YEAR
PERCENT INCREASE
1960 TO
IN MI

GROWTH RATE OF OHIO RIVER TONNAGE AS RELATED TO 1960 TONNAGE



OHIO RIVER BASIN COMPREHENSIVE SURVEY

PROJECTED TRAFFIC
OHIO RIVER STUDY AREA

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE 14

OUTDOOR RECREATION DEMANDS

	1965	1980	2000	2020
Million Recreation-Days Annually	220	391	710	1,030

The projections are based on an analysis of eight activities - swimming, boating, water skiing, picnicking, camping, sightseeing, nature walks, and walking - as indicators of the outdoor recreation demands on water and related land resources. It was assumed that the 1960 visitation was equivalent to the supply and the average individual participated in 2.5 activities during a visit to an area in which the eight selected activities were available. It was considered that standard metropolitan statistical areas were focal points from which most of the recreation demand originated and that about 90 percent of recreation use occurred within 125 miles of the origination point. Details on demands for recreation are given in "Appendix H: Outdoor Recreation." Figure 15 illustrates the 1965 and projected desires for outdoor recreation within the basin, together with hunting and fishing. Subbasin summary data for 1960 and projected demands are provided in table 11.

64. Fishing and hunting. - Gross demands for fishing and hunting were determined through analyses of locally developed use inventories supplemented by regional statistics and data from the "1960 National Survey of Fishing and Hunting," by the Bureau of Sport Fisheries and Wildlife. Indices for projecting were selected from functions of leisure time, desire to participate, license sales, availability of hunting and fishing opportunity, and residential environment. These factors were applied to projected populations. "Appendix G: Fish and Wildlife Resources," prepared by the Bureau of Sport Fisheries and Wildlife and the Bureau of Commercial Fisheries, provides the details of the demand for these activities and the resources available in the basin.

65. In 1960, 2.6 million sport fishermen engaged in 21.8 million angler-days on 591,000 acres of ponded waters and 46,000 miles of fishable streams in the basin. The national survey indicated that 8 percent of the adult population would have liked to take up fishing, and 13 percent of those who did fish would have liked to fish more than they did.

Future demand for commercial fishing is based on an increased per capita consumption of fresh water fish products. The 1960 commercial catch in the basin was 2.5 million pounds of fish and 2.3 million pounds of shellfish. Although commercial fishing is not of major significance in the economy of the basin, a potential for increasing the commercial fish harvest is available in the lakes and streams. Improved habitat, better management programs, and effective regulations are required to meet projected demands. Also, extensive modernization of commercial fishery harvesting, processing, and marketing techniques and organization will be required.

Approximately 2.3 million hunters enjoyed 21.7 million days of hunting in 1960. Over 1 million adults in that year would have liked to take up hunting, while 5 percent of the hunters would have liked to hunt more. A major problem in providing for needed hunting opportunity is the poor distribution of existing facilities. Future hunting areas must be made more attractive or located closer to areas of demand. Substantial future demands will have to be met on private lands. Intensified management of all habitat which provides hunting opportunities and more effective hunting regulations are needed.

The following is a summary of the 1960 use and projected gross demands for the Ohio River Basin:

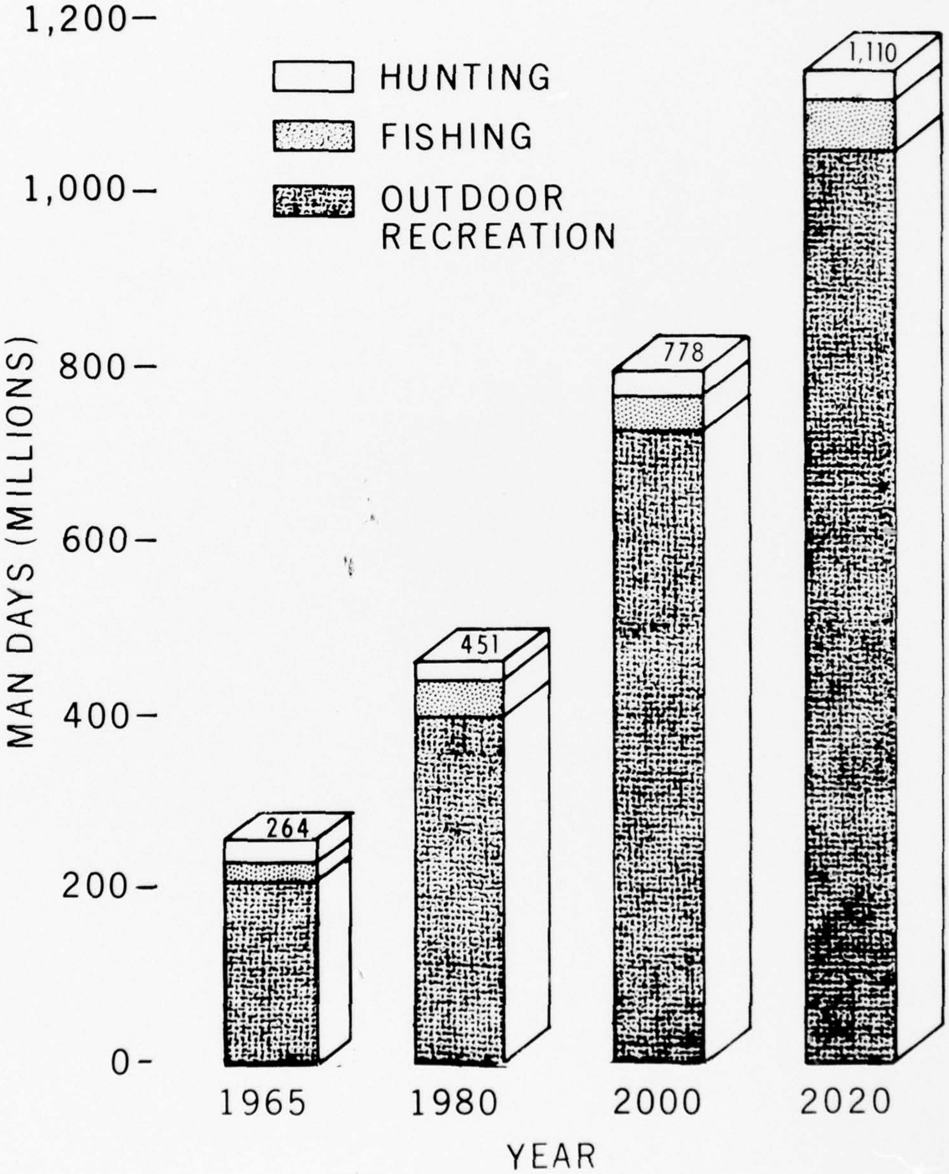
	1960	1980	2000	2020
		Millions		
Angler-Days	21.8	35.2	40.7	51.8
Hunter-Days	21.7	25.5	26.6	28.6
Commercial Fish Catch, Pounds	2.5	14.2	20.9	27.5

Demands for sport fishing and hunting are given in tables 12 and 13 of this appendix and are shown in figure 15. Details are covered in "Appendix G: Fish and Wildlife Resources."

66. Related lands. - Although all lands in the basin are considered part of the resources which contribute to and influence in various ways the water resource development of the region, only certain lands can be identified as closely water-resource-related. A distinction therefore is made between the basin's total 104 million acres which will require management considerations in order to better serve the socio-economic needs of the basin and that part related to streamflow control or in-place use of water. Figure 16 shows 1960 land use and projected changes to 2020. Figure 17 shows crop, livestock, and timber demands.

As regards total basin needs, rehabilitation of mining lands, particularly the 742,800 acres disturbed by strip mining, is an urgent requirement. Forest management, including better fire prevention and insect control, will also need additional attention. The 1965 and projected gross land development needs are summarized as follows:

	1965	1980	2000	2020
		Thousand Acres		
Land Treatment and Management	3,443	21,812	42,856	54,474
Irrigation	91	215	774	1,419
Drainage	12,088	15,348	16,162	16,617

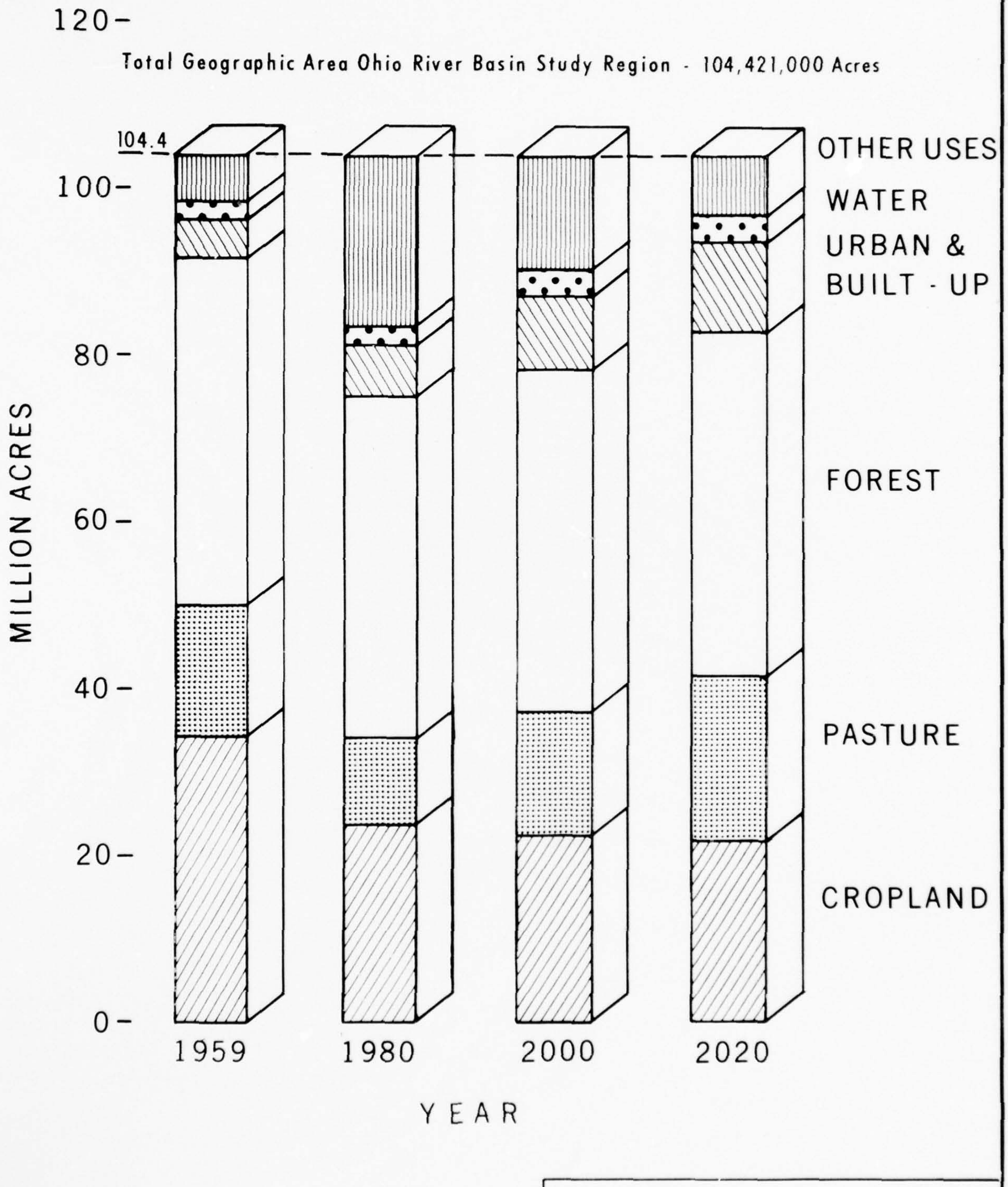


OHIO RIVER BASIN COMPREHENSIVE SURVEY

RECREATION, HUNTING AND FISHING GROSS DEMANDS

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE 15

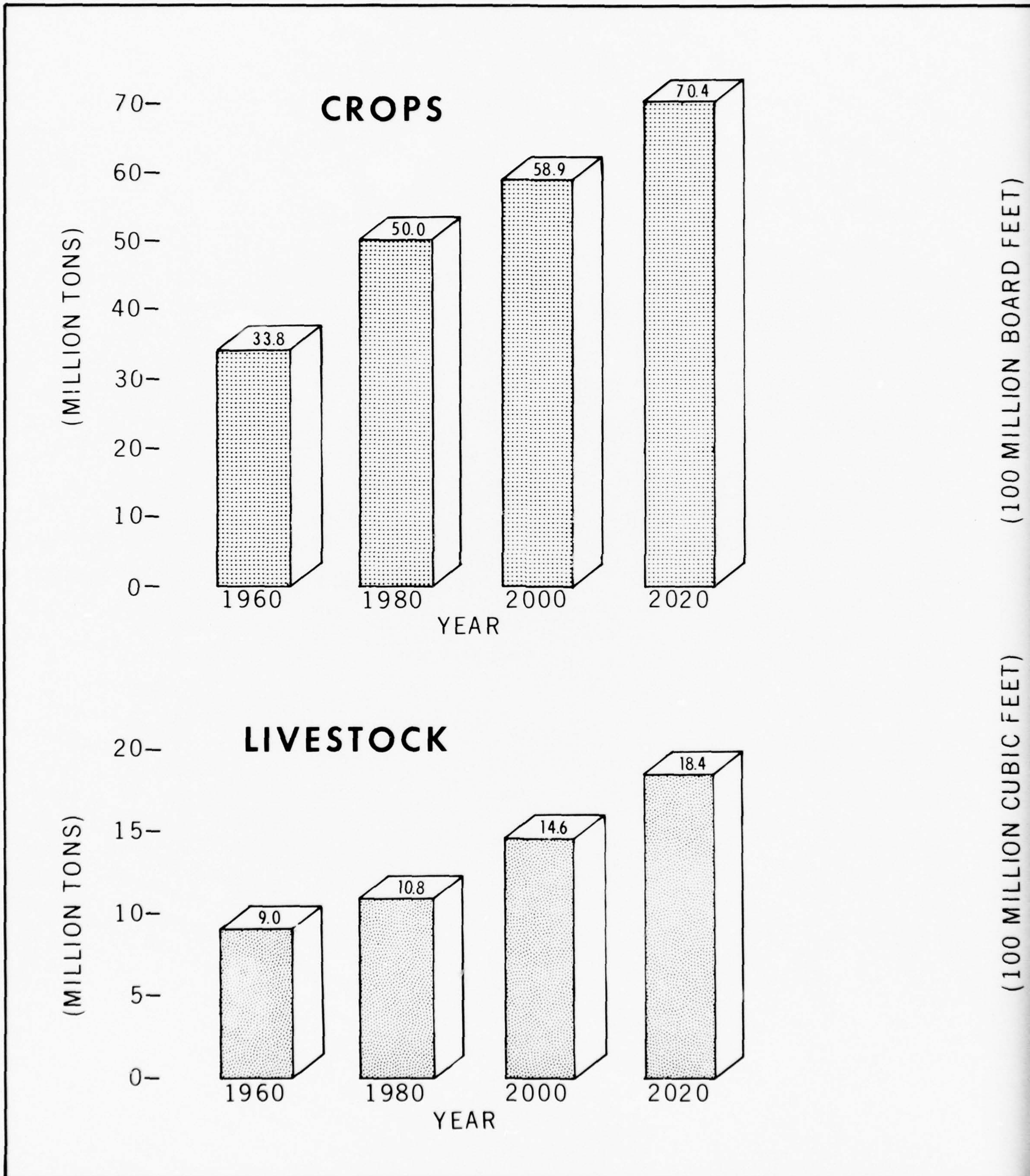


OHIO RIVER BASIN COMPREHENSIVE SURVEY

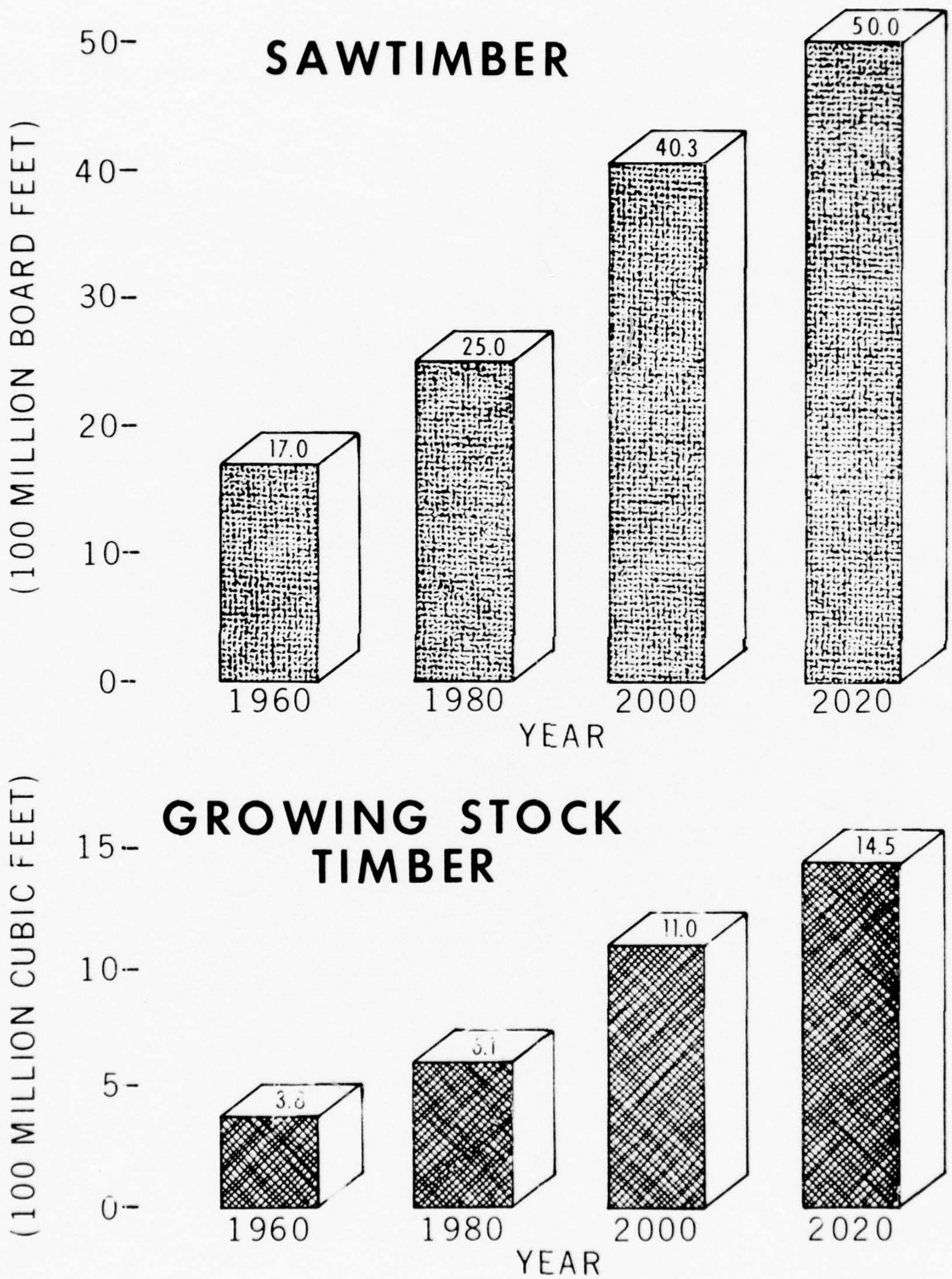
LAND USE

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE 16



CROPS
(MILLION TONS)
70
60
50
40
30
20
10
0
33.8
50.0
58.9
70.4
1960
1980
2000
2020
YEAR
LIVESTOCK
(MILLION TONS)
20
15
10
5
0
9.0
10.8
14.6
18.4
1960
1980
2000
2020
YEAR



OHIO RIVER BASIN COMPREHENSIVE SURVEY

CROP, LIVESTOCK AND TIMBER DEMANDS

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE 17

67. The Water Resources Council's guidelines for framework studies define related lands as "That land on which projected use and/or management practices may cause significant effects on the runoff and/or quantity and/or quality of the water resource to which it relates." Related lands include the lands directly utilized for water resources projects and adjacent lands necessary for operation and use of the development. These are defined in the plan formulation procedures as part of the water resources and related land development program.

68. Environmental factors. - Nature's bounty is being squeezed by population increases and the technological and economical pressures of man's desire to better himself. In serving this end, the land has been ravaged, the streams polluted, and areas of quiet and solitude are hard, if not impossible, to find. And yet, with greater income and more leisure time, man's search for his historical background and a better environment becomes more intensified.

In the development of water and related land resources, the consideration of environmental factors is greatly increasing in importance. Through proper planning and implementation, this development can enhance the environment in many instances. For example, reduction of floods and sustained streamflows may increase wildlife habitat, assure "white water" the year around, and contribute to the aesthetics themselves or make areas of natural beauty more accessible. Human and social values must be more closely defined to provide sound guidance in evaluating alternatives. The benefit of a beautiful scene cannot be evaluated in dollars and cents, and yet, the means of passing judgment on this worth in regard to changes brought about by resource development must be made available. As stated in Senate Document No. 97, 87th Congress, the "Well-being of all the people shall be the overriding determinant in considering the best use of water and related land resources. Hardship and basic needs of particular groups within the general public shall be of concern, but care shall be taken to avoid resource use and development for the benefit of a few or the disadvantage of many." The technology to serve any of man's desires is available; however, in the final analysis, the voice of the people and willingness to pay will be determining in providing for these desires.

In implementing the projects needed to fulfill the goals set forth in the framework plan, early consideration of the environmental factors is necessary to blend the views of many disciplines into a product that serves the Ohio Basin and the Nation best. Preservation of historic sites, areas of rare ecological or archeological value, or scenic sites must be considered in water and related land development. The framework study for the Ohio River Basin has not defined specific sites because project selection was not a part of the program. However, as sites are chosen for the implementation of the program and detailed planning progresses, environmental factors must be fully considered throughout the entire project formulation process.

REQUIREMENTS FOR PRODUCTS AND SERVICES

GOING DEVELOPMENT PROGRAMS

69. Water resource management and development programs are continuously being modified to fulfill changing requirements occasioned by changes in technology and economic trends, people's desires, and other factors. The following is an assessment of the going programs for water and related land resource development. Part of the program is Federal, but a large part is accomplished by State, local, and private interests either as jointly financed projects or as independent but coordinated actions. Large multipurpose programs, having widespread benefits and consequences, must necessarily be the responsibility of many levels of interests which range from private to Federal.

The going development program of resource development, management, and use includes the following: (a) Corps of Engineers facilities and measures that were existing, under construction, or under planning for construction as of July 1965, and also the Mound City and Smithland locks and dams, Ohio River, which by the end of 1965 had entered preconstruction status, (b) PL 566 watershed projects authorized as of July 1965, (c) non-Federal reservoirs completed by that date, and (d) other development and management programs, by Federal and non-Federal agencies and by private interests, which were in effect at that time. Although the various programs included are apparently at different milestones in their development, the common yardstick applied for establishing their status as "in the going program" is that they are either in existance or positive actions have been taken to provide reasonable assurance that they will continue, essentially as programmed, through completion. The following is a resume of the going water and related land resource development programs available or planned to serve present and projected demands.

70. The oldest and largest basinwide development programs have been agricultural drainage, navigation, and flood control. Over one-tenth of the study region lands have agricultural underdrains which make the rich, but relatively tight soils, very productive. About 80 percent of the drained lands are in the States of Ohio and Indiana.

The Ohio River waterways system is an integral part of the Mississippi-River-Gulf Intracoastal Waterway system. The 27 billion ton-miles of traffic carried in 1965 on the Ohio River and its tributaries, excluding the Tennessee River, amounted to over 25 percent of the total U.S. internal waterborne commerce. The navigation facilities provide slack water on the Ohio River for its entire length of 981 miles and for 1,131 miles on tributary streams in the study area. A depth of 9 feet or more is maintained on the Ohio River and 689 miles of the tributaries. The remaining tributary channels are maintained at lesser depths. The facilities are being continuously modified to serve increasing needs. Original locks and dams on the Ohio River are being replaced by higher lift structures to provide deeper and

longer pools (one is nearly 114 miles in length) and to reduce the number of structures from 33 (in July 1965) to 19. Lock sizes on the Ohio River are being increased to 110 by 1,200 feet. Replacement programs are also underway on certain tributaries. The total system is illustrated on figure 18. Details of Ohio River Basin navigation facilities are given in "Appendix L: Navigation."

The July 1965 water resources development program of the Corps of Engineers included about 28 million acre-feet of reservoir storage, of which about 17 million was for flood control. Flood control programs also included 372 miles of levees and floodwalls and 207 miles of channel improvements. Figure 19 shows the location of Corps of Engineers reservoirs, local flood protection projects, and navigation locks and dams in the going programs. Impoundments for navigation on the Ohio River and the tributaries, excepting the Cumberland River, do not serve a flood control purpose. Purposes served by reservoirs in the program are given in the following tabulation:

Purposes Served by Corps of Engineers Storage Projects

Purpose	Completed	Under Construction	Preconstruction Planning	Total
Flood Control	40	23	12	75
Low Flow Augmentation	9	11	6	26
Water Supply	3	1	4	8
Hydroelectric Power	3	3	0	6
Recreation, Fishing, and Hunting	40	24	12	76
Total Number of Reservoirs	40	24	12	76

Data on the program are given in tables 15 and 19. Although many of the earlier reservoir projects have been designed, built, and operated under a multiple-purpose concept in its broadest connotation, a primary purpose (usually flood control) had often prevailed over other purposes considered largely incidental. Relative importance of the various aspects of water control established the pattern. Industrial growth and an expanding population have brought substantial change to the overall framework of relative needs and values, and many of these projects have become truly multipurpose. Most of the projects have seasonal pools for recreation and conservation. At the end of the flood season, the pools are raised to conserve surplus waters and provide improved recreational conditions. The release, at the end of the recreation season, of this stored water provides flow supplementation during the fall when needed for quality control.

REQUIREMENTS FOR PRODUCTS AND SERVICES

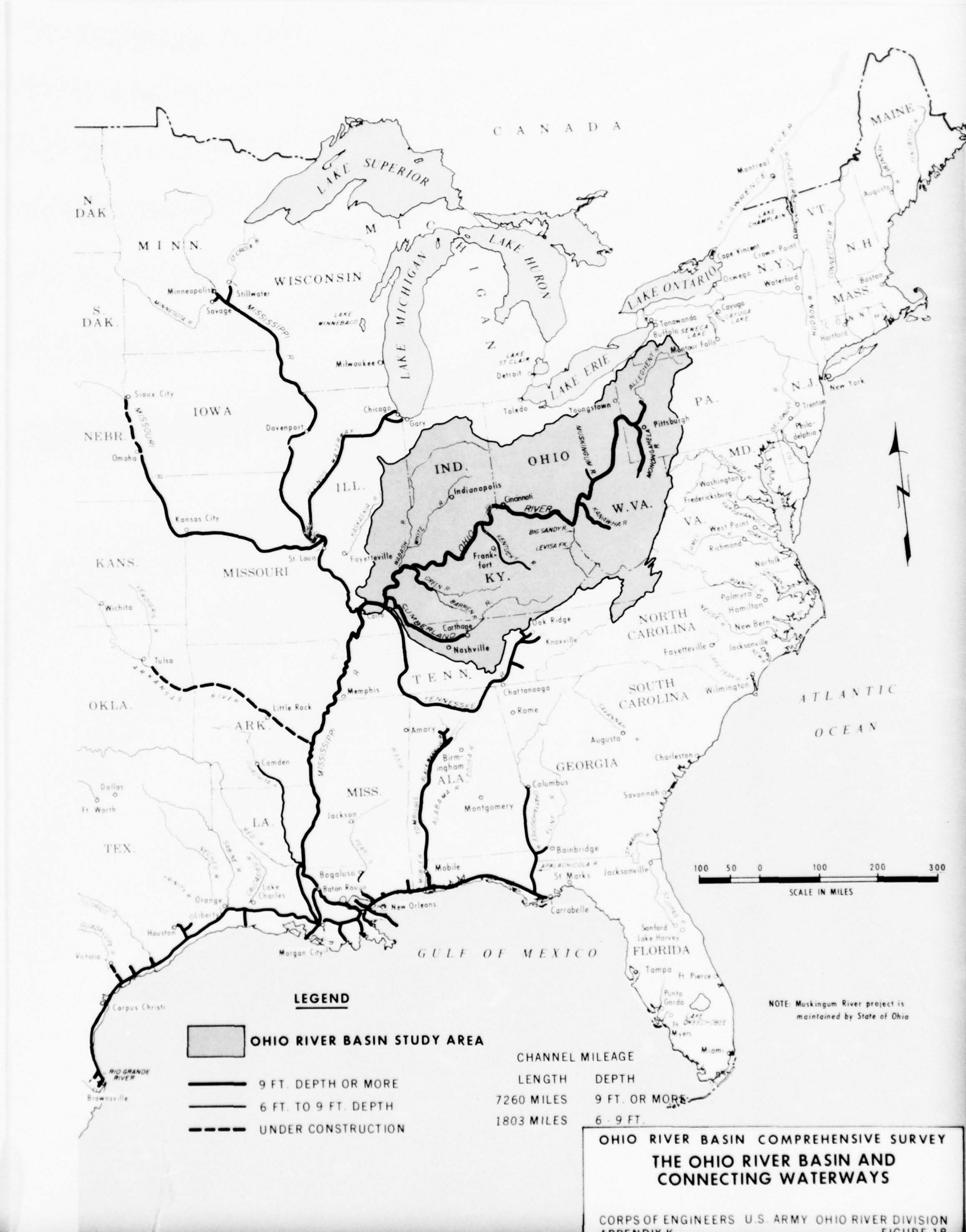
The Ohio River Division of the Corps of Engineers has launched a program to modernize the functional operation of completed reservoir projects. In anticipation of a substantial upgrading of computer and communication facilities, analytic procedures are being programmed to provide for day-to-day evaluation of the overall basin water resource, including the effects of reservoir regulation. This capability for rapid analysis of large volumes of data will provide a means of operating projects more effectively on a comprehensive systems basis.

On August 10, 1966, the President issued Executive Order No. 11296 directing all Federal agencies to evaluate flood hazards in locating federally owned or financed buildings, roads, and other facilities and in disposing of Federal lands and properties.

71. The Flood Control Acts of 1936, 1938, and 1944 vested in the Department of Agriculture responsibility for "* * * investigations of watersheds and measures for run-off and waterflow retardation and soil erosion prevention on watersheds * * *." Increased attention to watershed problems resulted in the initiation of pilot projects in 1953 and the enactment of Public Law 566, the Watershed Protection and Flood Prevention Act, in 1954. This act was to fill the gap in resource development between larger reservoirs and individual on-farm conservation measures. Local and State agencies are responsible for program obligations. Since passage of the act, the number of watershed projects has been rapidly increasing. This trend is expected to continue. The going program includes authorization for construction of detention structures and channel improvements in 74 basin watersheds. Subbasin summary information is given in table 16. Project data are given in table 20, and locations are shown on figure 19. The going program provides 961 miles of channel improvements and 440 floodwater retarding structures with 413,000 acre-feet of storage space, of which 44,000 are for sediment accumulation, 284,200 for storage of floodwater, and 84,800 for other water uses. Protection will be afforded to 205,000 acres of upstream flood plain. A number of projects are added each year. Details of the program are discussed in "Appendix F: Agriculture."

72. The Department of Agriculture has programs to provide technical and financial assistance in the planning and development of forest and land managemet programs, including irrigation and drainage, for privately owned areas. The Forest Service has a program to improve on Federal lands the forest cover which reduces sediment and helps retard runoff. These programs are discussed in detail in "Appendix F: Agriculture."

73. Soil and water conservation districts, organized under State and Commonwealth laws, have been established in 98 percent of the study area. These districts are governed by local people and provide assistance to farmers, ranchers, and land owners, as well as local and State agencies, in planning and applying conservation, management, and land treatment measures. As of July 1965, the districts provided assistance in the preparation of 162,877 conservation plans in the basin. Their goal is to use each acre of land within its capabilities and to treat it according to its needs. More efficient farm operation, higher incomes, and watershed protection from erosion result from this program of improvements.

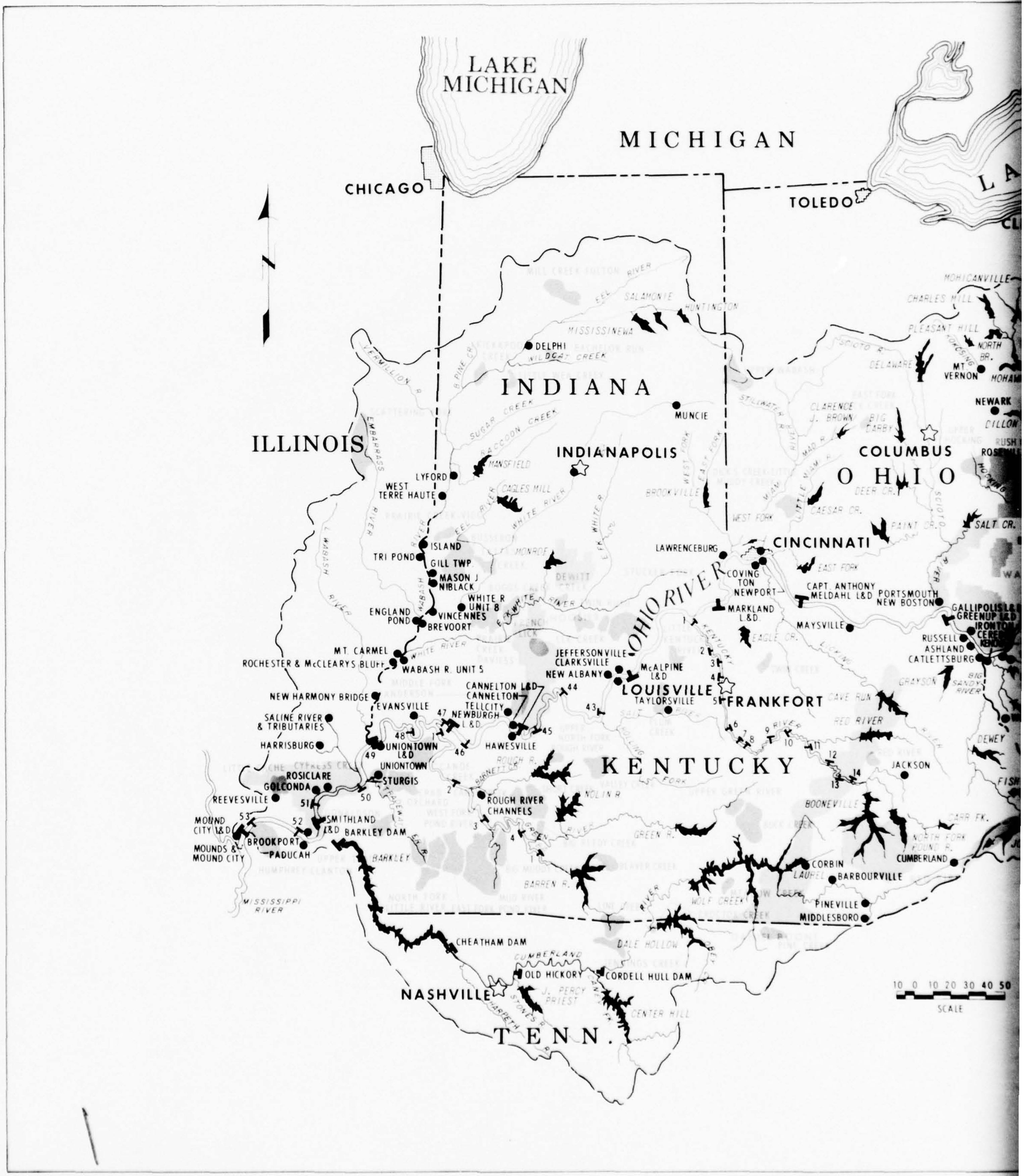


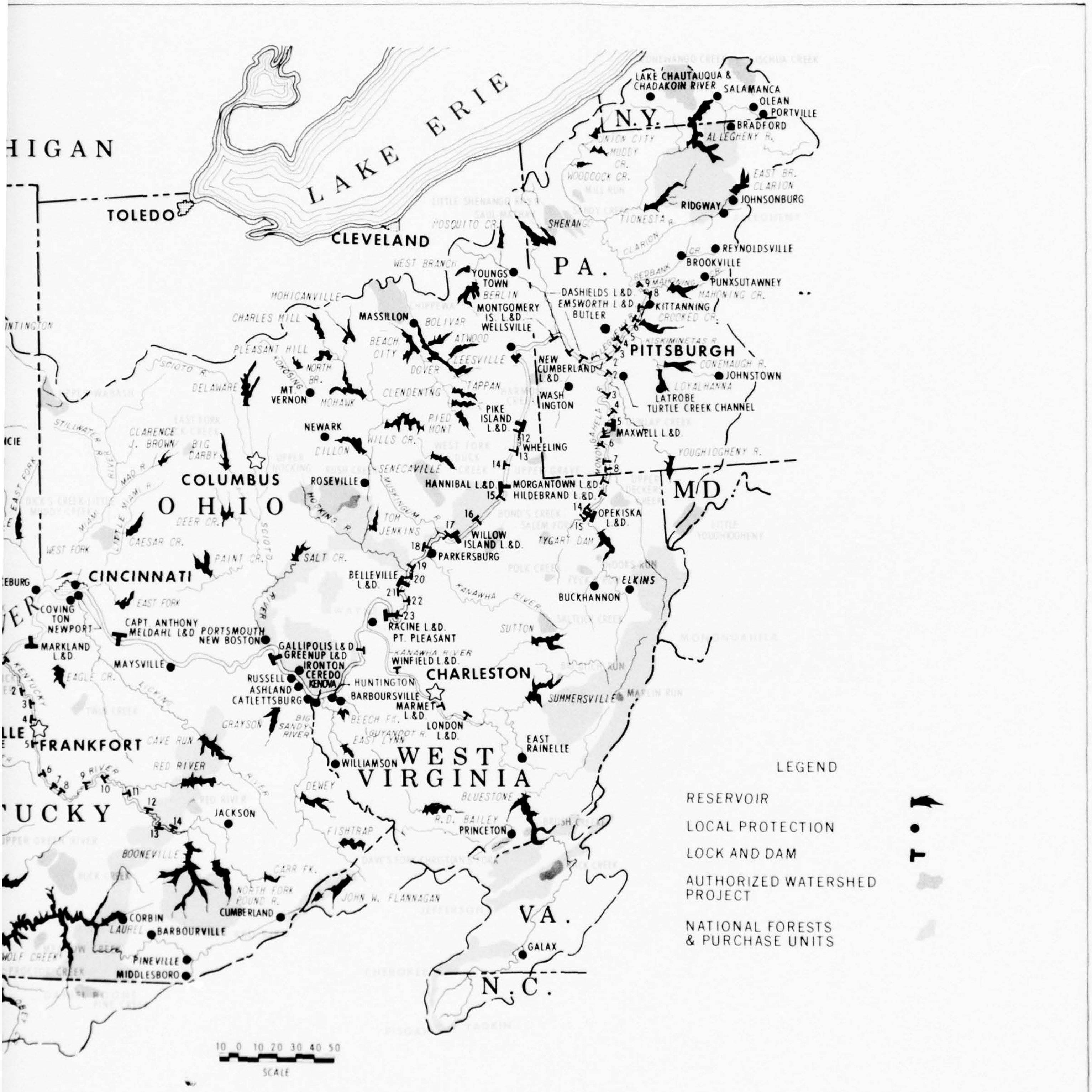
OHIO RIVER BASIN COMPREHENSIVE SURVEY

THE OHIO RIVER BASIN AND CONNECTING WATERWAYS

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE 18


LAKE MICHIGAN
MICHIGAN
CHICAGO
TOLEDO
ILLINOIS
INDIANA
OHIO
KENTUCKY
TENN.
OHIO RIVER
MISSISSIPPI RIVER
INDIANAPOLIS
COLUMBUS
CINCINNATI
LOUISVILLE
FRANKFORT
NASHVILLE
DELPHI
MUNCIE
LYFORD
WEST TERRE HAUTE
MANSFIELD
ISLAND
TRI POND
GILL TWP.
MASON J NIBLACK
WHITE R UNIT 8
ENGLAND POND
VINCENNES
BREVOORT
MT. CARMEL
ROCHESTER & McCLEARYS BLUFF
WABASH R. UNIT 5
NEW HARMONY BRIDGE
EVANSVILLE
SALINE RIVER & TRIBUTARIES
HARRISBURG
UNIONTOWN L&D
UNIONTOWN
STURGIS
ROSICLARE
GOLCONDA
REEVESVILLE
MOUND CITY L&D
MOUNDS & MOUND CITY
BROOKPORT
PADUCAH
SMITHLAND L&D
BARKLEY DAM
CANNELTON L&D
CANNELTON
TELLCITY
NEWBURGH L&D
HAWESVILLE
ROUGH RIVER CHANNELS
JEFFERSONVILLE
CLARKSVILLE
NEW ALBANY
McALPINE L&D
TAYLORSVILLE
LAWRENCEBURG
COVINGTON
NEWPORT
MARKLAND L&D
CAPT. ANTHONY MELDAHL L&D
PORTSMOUTH
NEW BOSTON
MAYSVILLE
GALLIPOLIS L&D
GREENUP L&D
RUSSELL
ASHLAND
CATLETTSBURG
JACKSON
CORBIN
BARBOURVILLE
PINEVILLE
MIDDLESBORO
CUMBERLAND
CHEATHAM DAM
OLD HICKORY
CORDELL HULL DAM
MOHICANVILLE
CHARLES MILL
PLEASANT HILL
NORTH BR.
MT VERNON
DELAWARE
NEWARK
DILLON
CLARENCE J. BROWN
BIG DARBY
SALT CR.
PAINT CR.
DEER CR.
CAESAR CR.
BROOKVILLE
SCALE
10 0 10 20 30 40 50



OHIO RIVER BASIN COMPREHENSIVE SURVEY

1965 FEDERAL GOING DEVELOPMENT PROGRAM

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K

FIGURE 19

Some of the more common management and treatment measures emphasized by soil and water conservation districts are contour farming of all types, controlled grassland farming, and improved forest management and utilization. These practices, which reduce erosion and runoff rates, have been applied to 22 million acres.

Conservancy and watershed districts play an important role in water and related land resources planning and development. Two notable achievements are those of the Miami Conservancy District and the Muskingum Watershed District. In cooperation with Federal and State agencies, the Miami Conservancy District built five detention dams and other flood protection structures during the period 1915-1922. The detention dams are supplemented by 53 miles of levees and approximately 43 miles of channel improvements through urban areas. The 14 Muskingum Basin reservoirs, built by the Federal Government in cooperation with local interests during the period 1934-1936, are authorized for flood control and water conservation and provide recreational opportunities.

Information on the Miami Conservancy District retardation structures is included in table 17 with the data on non-Federal reservoir projects with pool areas greater than 200 acres or storage over 1,000 acre-feet. Many of these are municipally or privately owned. They provide storage for hydropower, water supply, recreation, and fish and wildlife. Location of non-Federal impoundments are shown in figure 20. Non-Federal local flood control project data are given in table 18. Table 19 summarizes, by subbasins, data on major reservoirs in the 1965 Federal program.

The Weather Bureau of the U.S. Environmental Science Services Administration operates a flood forecasting service for the Ohio River and its major tributaries. This service, in the form of forecasts and warnings, provides in most instances time for evacuation of people, emergency protection of property, and removal of some contents of flood plains. Past estimates by the Weather Bureau have indicated that flood warning systems have saved about 10 percent of potential flood damages and have reduced the potential loss of life by 90 percent. Data from more recent events indicate even greater savings.

The 1965 flood control program, consisting of reservoirs, upstream detention structures, local protection projects, and other structural measures, reduces gross potential damages by about two-thirds to approximately $111 million.

Federal and private hydroelectric projects which were completed or under construction in the basin as of 1965 have an installed capacity of 1,503 megawatts. The location and capacity of the projects are given in table 21.

74. State, local, and private interests cooperate in planning, developing, and financing water supply treatment plants and distribution systems, flood control, recreational developments at reservoirs, sewerage collecting systems, and waste treatment facilities. States have programs for flood control, recreation development, public health and sanitary facilities,

conservation of land and forests, preservation of historic and cultural sites, and such basic things as data collection. The Federal Government assists in many of these endeavors by providing funds and technical assistance. Most States, through their universities, have research programs for improved use of water and related land. They also provide guidance in attracting business and industry and in planning for their development and the betterment of the socio-economic environment.

75. Details of State and local organizational elements, laws, policies, and programs, as well as an inventory of non-Federal water resource projects are given in "Appendix J: State Laws, Policies, and Programs." The following table gives an indication of the magnitude of the State and other non-Federal efforts in providing for control and use of available water resources:

Non-Federal Developments	Number of Projects
Municipal Water Distribution Systems (1963 Inventory)	1,908
Municipal Water Treatment Plants (1963 Inventory)	1,597
Municipal Sewerage Systems (1962 Inventory)	1,293
Industrial Waste Treatment Facilities	1,550
Farm Ponds	162,000
Agricultural Drainage (12 Million Acres)	NA

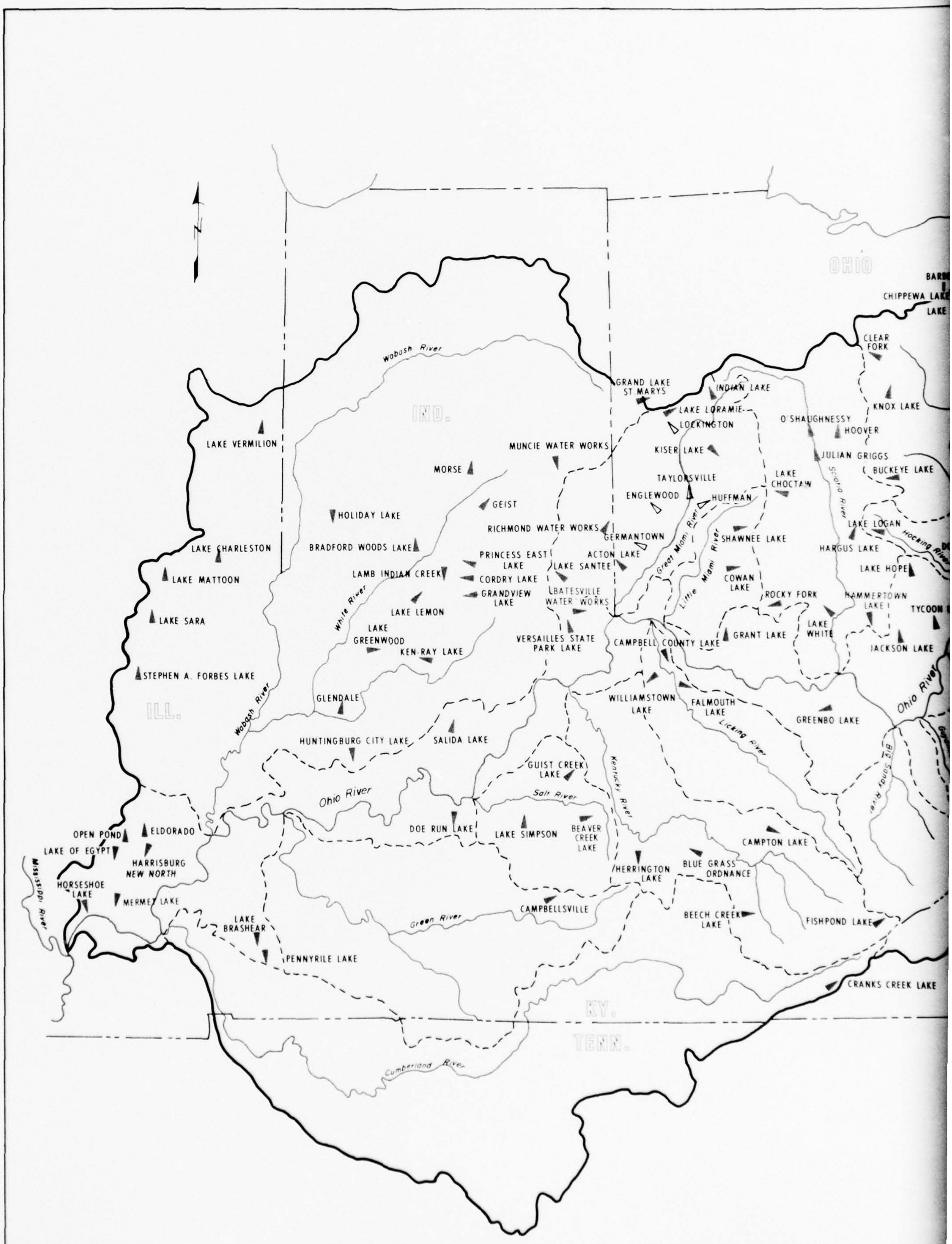
76. In 1948, eight States of the Ohio River Basin joined with the Federal Government in a regional crusade for clean streams and formed the Ohio River Valley Water Sanitation Commission (ORSANCO). Over 95 percent of the Ohio Basin study region is under the water quality management jurisdiction of ORSANCO. The commission's 1965 annual report summarizes the result of this continuing effort as follows:

* * * * * * *

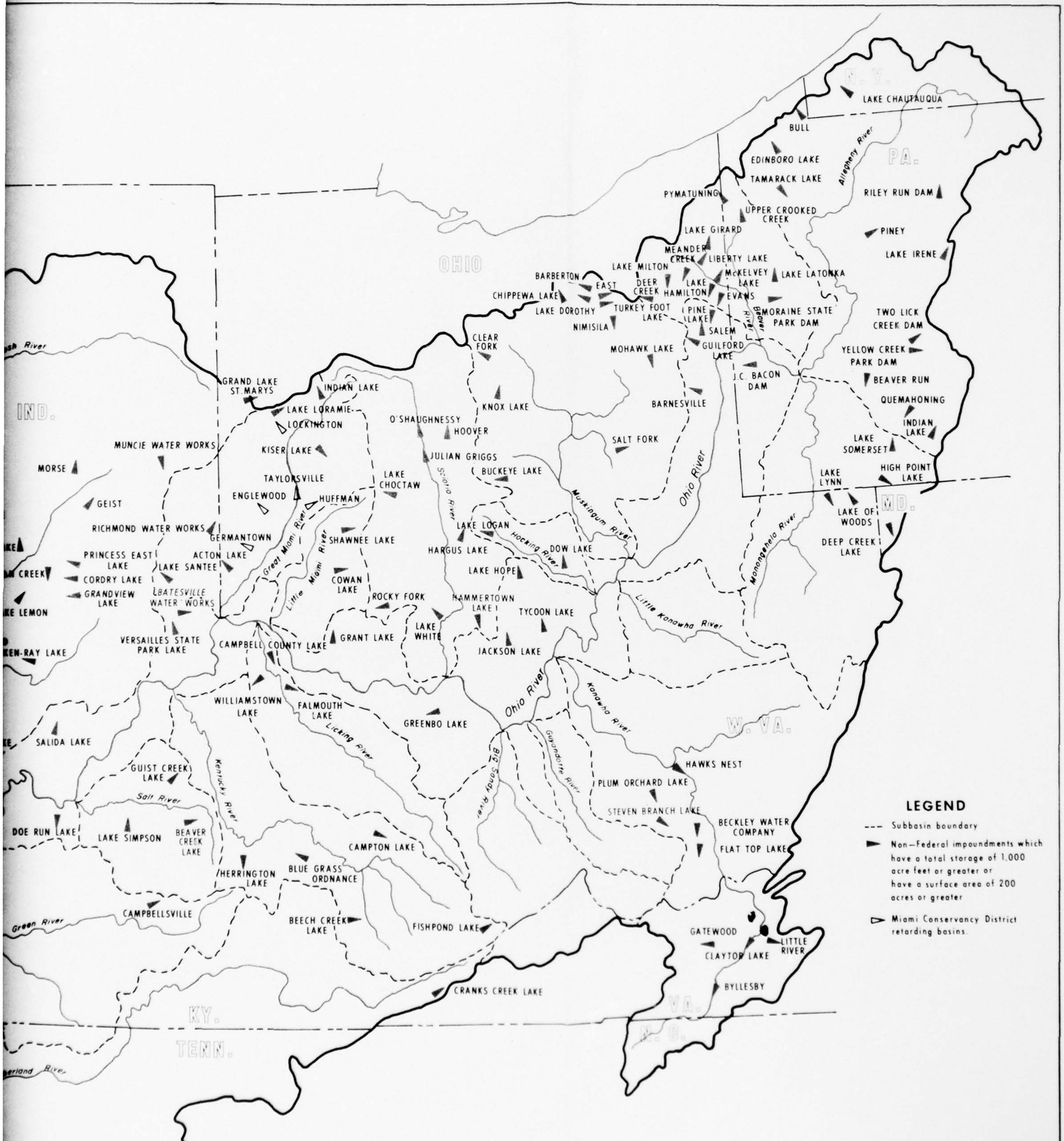
"The Ohio River is at least $370 million cleaner than it was in 1948. And on the tributaries another $748 million has been invested by communities for installation of sewage-treatment facilities during the past seventeen years.

"Local funds have financed nine-tenths of this capital outlay for stream cleanup. Federal grants-in-aid to municipalities, which did not become available until 1956, account for the remainder.

"Expenditures by industries for pollution abatement are not a matter of public record. The states report that 1,560 of the 1,723 establishments discharging effluents to streams have installed control facilities. On one tributary, the Kanawha in West Virginia, nine companies have reported costs aggregating $18 million to complete the first phase of a two-stage control program.



N
OHIO
IND.
ILL.
KY.
TENN.
Wabash River
White River
Ohio River
Mississippi River
Green River
Cumberland River
Salt River
Kentucky River
Licking River
Great Miami River
Little Miami River
Scioto River
Hocking River
Big Sandy River
LAKE VERMILION
LAKE CHARLESTON
LAKE MATTOON
LAKE SARA
STEPHEN A. FORBES LAKE
OPEN POND
ELDORADO
LAKE OF EGYPT
HARRISBURG NEW NORTH
HORSESHOE LAKE
MERMET LAKE
MORSE
GEIST
HOLIDAY LAKE
BRADFORD WOODS LAKE
LAMB INDIAN CREEK
PRINCESS EAST LAKE
CORDRY LAKE
GRANDVIEW LAKE
LAKE LEMON
LAKE GREENWOOD
KEN-RAY LAKE
GLENDALE
HUNTINGBURG CITY LAKE
SALIDA LAKE
MUNCIE WATER WORKS
RICHMOND WATER WORKS
GERMANTOWN
ACTON LAKE
LAKE SANTEE
BATESVILLE WATER WORKS
VERSAILLES STATE PARK LAKE
GRAND LAKE ST. MARYS
INDIAN LAKE
LAKE LORAMIE
LOCKINGTON
KISER LAKE
TAYLORSVILLE
ENGLEWOOD
HUFFMAN
LAKE CHOCTAW
SHAWNEE LAKE
COWAN LAKE
ROCKY FORK
O'SHAUGHNESSY
HOOVER
JULIAN GRIGGS
BUCKEYE LAKE
KNOX LAKE
CLEAR FORK
CHIPPEWA LAKE
LAKE LOGAN
HARGUS LAKE
LAKE HOPE
HAMMERTOWN LAKE
TYCOON
LAKE WHITE
JACKSON LAKE
GRANT LAKE
CAMPBELL COUNTY LAKE
WILLIAMSTOWN LAKE
FALMOUTH LAKE
GREENBO LAKE
GUIST CREEK LAKE
DOE RUN LAKE
LAKE SIMPSON
BEAVER CREEK LAKE
CAMPTON LAKE
HERRINGTON LAKE
BLUE GRASS ORDNANCE
CAMPBELLSVILLE
BEECH CREEK LAKE
FISHPOND LAKE
LAKE BRASHEAR
PENNYRILE LAKE
CRANKS CREEK LAKE



OHIO RIVER BASIN COMPREHENSIVE SURVEY

1965 GOING PROGRAM
NON-FEDERAL IMPOUNDMENTS

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION
APPENDIX K FIGURE 20

> "These local expenditures of more than a billion dollars represent a measure of response thus far in advancing aspirations of the Ohio River Valley Water Sanitation Compact. The result is that 93 percent of the sewered population in the valley is now served by sewage disposal works, half of which provide secondary treatment and another quarter employ intermediate processing.
>
> "In addition, 90 percent of the industrial establishments are listed as having made provisions for waste control that meet minimum interstate requirements or better. However, because this figure makes no differentiation between large and small plants, it should not be construed to mean that 90 percent of the pollutional load has been abated. * * *

* * * * * * *

The surveillance of pollution has been a continuing effort and a rewarding one. Achievements of the States comprising ORSANCO warranted the Civil Engineering Award in 1963. The award is presented annually by the American Society of Civil Engineers for an outstanding project or program.

77. Recreation facilities and enhancement of fish and wildlife are the responsibilities of Federal, State, and local jurisdictions. Nearly all water resource projects for control of high and low flow or in-stream use provide new resources for recreation, fishing, and hunting opportunities. It is estimated that in 1965, 85 million recreation-days were served within the Ohio Basin study region at multipurpose water resource projects, in non-Federal areas, and in national forests and parks. Of the 22 million hunter-days and the 22 million angler-days, the portion satisfied at all water resource or related land projects was not determined. However, 3.2 percent of the total hunting occurred on public lands, and 36 percent of the fishing, on public waters.

An inventory of pleasure motorboats in 1965 indicated over 360,000 licensed craft in the study area. About 40 percent of these were moored on water, many of them on the Ohio River and its navigable tributaries. The remainder were trailer mounted.

78. Environmental factors have been given consideration in past water resource and related land developments. However, recent emphasis has increased the attention. Planning of water resource developments in the Ohio Basin has included the preserving of falls, caves, archeological areas, and unique ecological, historic, and scenic sites. The engineering design of projects includes consideration of scenic values

associated with site selection, road location, and rehabilitation of borrow pits, as well as an attention to the enhancement of other environmental factors. Wild and scenic reaches of rivers have been given consideration in planning. Yet, interests change, and until a project reaches the detailed planning stage, objections often are not known or voiced. The effect of man's activity on water and related land often is not recognized until too late to consider the impact. The significance of earth-moving, solid waste disposal, strip mining, logging, and other disturbance of the land often is not noted until these are well underway. In many cases, it has been the prerogative of State and local jurisdictions to decide whether or how these operations should be controlled.

NET REQUIREMENTS AND ASSOCIATED PROBLEMS

79. The net requirements for control and use of water and related land resources were evaluated by analyzing present and projected gross requirements and determining what part could be satisified by existing resources and going development programs. The following paragraphs provide an assessment of net requirements and associated problems.

80. Water withdrawal requirements. - Water supply requirements were measured in terms of average daily withdrawals and terms of consumptive use.

NET WITHDRAWALS FOR WATER SUPPLY - MILLION GALLONS PER DAY

		Additional Future Requirements		
	1965 Use	1980	2000	2020
Municipal	1,743	562	1,549	3,034
Manufacturing Industries	9,811	1,919	6,254	13,669
Electric Power Cooling	19,200	9,800	26,800	43,800
Mining	289	222	685	1,605
Rural, Nonfarm Domestic	587	86	207	347
Livestock	116	13	78	142
Farm Domestic	46	0	0	0
Irrigation	46	56	306	636
Total	31,838	12,658	35,879	63,233

NET AVERAGE CONSUMPTIVE USE - MILLION GALLONS PER DAY

	1965 Use	Net Needs 1980	2000	2020
Municipal	174	57	155	304
Manufacturing Industries	196	39	125	274
Electric Power Cooling	158	198	547	1,082
Mining	53	26	80	191
Rural, Nonfarm Domestic	391	58	139	232
Livestock	116	13	78	142
Farm Domestic	46	0	0	0
Irrigation	46	56	306	636
Total	1,180	447	1,430	2,861

81. The number of water supply problem areas will increase manyfold by 2020. By 1980, about 400 small towns and rural communities (as estimated by the U.S. Department of Agriculture) and 154 urban locations (as concluded by the Federal Water Pollution Control Administration) may have significant water supply problems. Major water use areas in the basin are at Pittsburgh, Pa., Indianapolis, Ind., Dayton and Columbus, Ohio, Charleston, W. Va., and major cities on the Ohio River. Details on net water supply requirements are given for each subarea in attachment A.

82. Assuming nearly all new fossil- or nuclear-fueled electrical generation installed after 1980 will utilize evaporative cooling, consumptive use through evaporation will total 1.4 million acre-feet per year by 2020.

83. Irrigation in an average year will require about 745,000 acre-feet of additional water by 2020. It is estimated that 2020 crop water needs will be supplied 40 percent from ground water; 30 percent from streamflow; and 30 percent from reservoirs.

84. Water quality control. - Even assuming secondary treatment of all sewage, there are nearly 200 stream reaches totaling several thousand miles in the Ohio Basin with organic waste water quality problems during low flow periods. Many more are expected in the future unless additional steps are taken to eliminate wastes at the source. There are also problems associated with other pollution substances, even during normal flows. Wastes from combined storm-sanitary sewers create local pollution problems primarily during thunderstorms or intense, local rainfall. Storm runoff into such systems in excess of treatment plant capacities often results in discharges being passed untreated to streams. Presently, wastes from about half of the population served by sewerage systems are being discharged into combined storm-sanitary sewers. It is estimated that about $3 billion would be required to change existing combined systems to separate systems.

85. Metropolitan Pittsburgh is the major waste contributor to the Allegheny and Monongahela Rivers and the upper Ohio River. The Kanawha River at Charleston, W. Va., the Great Miami at Hamilton, Dayton, and Middletown, Ohio, the Scioto at Columbus, Ohio, the Wabash at Indianapolis, Ind., and the Ohio River below major cities are stream reaches with major pollution problems. At many locations, organic waste problems are significantly intensified by discharge of heated water from thermal electric and other industrial plants. The Kanawha and Wabash River Basins have the largest and second largest amount, respectively, of the organic wasteloads generated in the basin tributaries. Kanawha and Putnam Counties in the lower Kanawha Basin account for 94 percent of the organic wasteload generated in the Kanawha River Basin. The metropolitan Indianapolis area accounts for about one-third of the domestic and commercial and one-half of the industrial organic loads in the Wabash Basin.

86. More than half of the acid drainage waters of the Ohio Basin originate in the Monongahela and Allegheny Basins. The Kiskiminetas River is one of the most acid-polluted streams and contributes about 80 percent of the acid carried in the lower Allegheny River. The Monongahela River Basin, containing more than 1,600 miles of acid-polluted streams, receives about 35 percent of the total acid drainage in the Ohio Basin. About 70 percent of this originates in the smaller tributaries which join the parent stream between Fairmont, W. Va., and Pittsburgh.

The Hocking River and Raccoon Creek contribute significant amounts of acid to the Ohio River. Some 300 miles of streams in the lower Wabash Basin are affected by coal mining wastes. The adjacent Saline River Basin has 60 miles of acid-polluted streams. The lower Green River Basin is extensively polluted by acid mine drainage, as is virtually the entire Tradewater Basin. Estimates indicate that the combined load from the Green and Tradewater Rivers is about 230 tons of mine acid (calcium carbonate equivalent) per day. Other concentrated acid pollution exists in the coal mining reaches of the Muskingum, Kanawha, Guyandotte, Big Sandy, Kentucky, and upper Cumberland Rivers. (See figure 10.)

87. Wasteheat disposal and pollution problems are presently of major importance in some locations in eight subbasins, the greatest problem being in the Mahoning and Green River Basins, where temperatures are raised far above normal. Flow supplementation for heat reduction is presently practiced in the Beaver Basin, but with increased industrial activity, additional measures will be required. The Columbus, Dayton, and Indianapolis areas have wasteheat disposal problems. Thermal electric plants in certain locations on the Allegheny and Monongahela Rivers and along the Ohio River would create problems.

Sediment is also a pollutant. Rehabilitation of strip-mine areas, agricultural and forest land management, bank stabilization, and other

measures are required to keep erosion under control. The measured rates from reservoir sedimentation surveys in the Ohio River Basin range from 0.02 to 1.31 acre-feet per year per square mile. Sediment transport damages fish life and contributes to reservoir silting problems; also, deposition in navigation channels and harbors increases dredging requirements. Sediment may be deposited from receding floodwaters with consequential damage to agricultural land, homes, and industrial and other property. Data on sedimentation are given in "Appendix C: Hydrology."

88. Chloride pollution is a serious problem in the Barberton area of the Muskingum River Basin and other areas in the Ohio Basin. The southwestern part of the Wabash Basin, containing the lower reaches of Patoka, Embarrass, and Little Wabash Rivers, includes oil-producing areas which contribute to the brine problem. Lesser brine problems exist in the Paint Creek in the Big Sandy Basin, the lower reach of Rough River in the Green Basin, and along some of the smaller tributaries of the Licking River in Kentucky. The Morrow County area, in Ohio, contributes some brine to the Scioto River, but the greatest part of the brines brought to the surface is reinserted to deep strata through wells. Potential problems in the Guyandotte and Little Kanawha Basins are apparently being controlled by the same method.

89. Determination of water requirements for quality control were based on streamflow required to sustain water quality standards during a once-in-10-year frequency of occurrence of a 7-consecutive-day minimum flow period with all wastes receiving secondary treatment. The streamflow requirements are given in Appendix D. Table 2 of each subbasin summary provides the assessment of flow requirements. The health aspects of water quality were not studied in detail, but increased attention to the problem is needed.

90. Flood control. - Potential basinwide flood damages remaining after completion of the going program for flood control and prevention, are estimated at $111 million annually with a development in the flood plains as of 1965. Without further improvements for flood protection and assuming an effective flood plain regulation program, the remaining potential annual flood damages in the basin are projected to reach $296 million by 2020. Flood damage data for present and future projected flood plain use are given in table 10 for Ohio River reaches and the subbasins.

Remaining average annual potential flood damages, with the 1965 development program in effect, range for major subbasins from $1,099 to $232 per square mile of drainage area. The Ohio River Basin average is $679 per square mile. Per square mile of flood plain, they range in the various subbasins from $62,050 to $4,118, whereas the Ohio Basin average is $9,560. On a per capita basis, the range is from $11.63 to $1.58 per year, with an Ohio Basin average of nearly $6.00.

The Wabash River Basin is highest in total annual damages, annual damages per capita, and annual damages per square mile. The Beaver Basin is high in total average annual damages and damages per square mile of flood plain, but low in annual damages per capita because of its relatively large population.

91. Locations with major urban flood problems are shown on subbasin maps in attachment A. Potential upstream watershed project areas, shown on these maps, contain a large share of the agricultural damages. There are 46 urban flood damage centers in the basin with residual average annual damages of $50,000 or more. Thirty-five of these centers have average annual damages in the range from $50,000 to $299,000; seven, in the range from $300,000 to $599,000; two, in the range from $600,000 to $999,000; and two, over $1 million. Pittsburgh, Pa., Indianapolis, Ind., as well as Columbus and Chillicothe, Ohio, each have average annual damages greater than $600,000. For the Ohio River flood plain, remaining potential damages total nearly $11 million annually. Agricultural areas along many reaches of tributary rivers, particularly in the Wabash and Scioto Basins, also have serious problems.

92. Navigation. - Completion of the locks and dams under construction and in preconstruction planning as of December 1965 will result on the Ohio River in a system of 19 dual locks. Except at four navigation structures (one near Gallipolis, Ohio, and three just below Pittsburgh) where existing facilities are inferior, the locks will have chambers, 110 by 1,200 feet and 110 by 600 feet. Net requirements for navigation above the capability of the going program are as follows.

	Traffic in 1965	1965 Program Capability	Projected Net Demand 1980	2000	2020
	Billion Ton-Miles				
Ohio River	23.3	34.0	8.0	42.0	93.0
Tributaries	4.0	8.6	.6	3.6	6.5
Potential New Waterways	0	0	1.2	4.5	6.1
Total Study Area System	27.3	42.6	9.8	50.1	105.6

Water transport needs to 1980 on the Ohio River can be served within the physical and operational limits of the lock and dam facilities when the remaining four locks are modernized under the current replacement plan. Additional improvements of lockage facilities, as well as increased waterway depths, are required in the tributaries. It appears that an increased depth of at least 12 feet throughout the Ohio system will be desirable by about 1980 for efficient operations. Increased channel depth is essential to provide the physical capacity required before 2020. A need exists also for new waterroutes between the Great Lakes and the Ohio River and along the Big Sandy River, Tug Fork, and the Wabash River. These potential new

waterways would serve 6.1 billion ton-miles of freight in the basin. Additional demand for waterborne freight transport exists along other tributaries, in particular the Saline, White, Great Miami, Licking, Little Miami, Scioto, Little Kanawha, and Muskingum Rivers. Needs in the areas adjoining the channel reaches of the tributaries into which extends slack water from the new Ohio River navigation pools are included in the Ohio River transport projections. Details on anticipated growth of waterborne freight traffic are presented in "Appendix L: Navigation." Recreational boating makes much use of the navigable waterways. Problems associated with congestion, safety, and pollution control are of significance.

The going program for control of high and low flows in the basin, under the established storage allocations and operational plans, will provide a supply of lockage water that will be adequate under conditions of optimum use of lock capacities. Additional control of high flows would improve navigation conditions on waterways by increasing the portion of time during which bridge clearances remain adequate and by reducing the time during which locks are shut down due to floodflows.

93. Outdoor recreation. - Recreational needs are greatest near major metropolitan areas. Projected recreation needs to 1980, 2000, and 2020 are given in table 11. Details are found in "Appendix H: Outdoor Recreation." The estimated ultimate recreation use at Federal reservoirs in the going program and at potential future watershed projects is shown in tables 26 and 27.

The net requirements over the 1965 supply of 85 million recreation-days are summarized as follows:

	Million Recreation-Days		
	1980	2000	2020
TOTAL NET REQUIREMENT	306	625	945

94. Fishing and hunting. - The unsatisfied need of 3.1 million angler-days by 1980 and about 15 million by 2020 will require additional or improved fish habitats and access to sport fishing areas, beyond those presently scheduled or planned. Table 12 provides 1960 and projected demands by subbasins.

The projected demands for commercial fishing will require increased use of the available habitat. The 1960 production rate of 12.8 pounds per acre of fish habitat will need to be increased to over 22 in 1980, and 42 in 2020. These increases are well within the resource potential; but improved fishing and processing methods, better habitat management, and effective fishing regulations are required to meet the demands for over 25 million pounds of commercial fish catch by 2020.

An additional 3.4 million man-days of hunting opportunity will be needed by 1980, and 6.5 million, by 2020. Table 13 presents, by subbasins, 1960 and projected demands. As in the case of fishing resources, hunting opportunities in some subbasins exceed the demand. Some of these surpluses are available to serve demands in other subbasins.

95. Related land. - Although all lands in the basin are a part of the resources of the region, only a portion can be considered as land significantly related to water resource development. This is land that is associated with developments of water resources either through the effects of the land on the water resources or the effect of the water resources and their development features on the land. "Related land" is the land on which projected use and/or management practices may cause significant effects on the runoff and/or quantity and/or quality of the water resources to which it relates. It includes land which is feasible for irrigation, land that contributes excessive amounts of sediment or other pollutants, flood plain lands which can be protected, lands which are inundated by project development, lands the administration and management of which may be affected by construction of a reservoir or other water resource developments, and land the use or productivity of which is affected by a change in water level caused by a water resource development.

Of the 8 million acres of flood plain lands, 6.4 million are subject to protection. Future reservoirs and other water resource developments may inundate 2.5 million acres and require an added similar-size area for adjoining lands development that should be managed together with the project.

The following summarizes the total future needs for land treatment and management in the basin:

	1980	2000	2020
Land Treatment and Management................million acres..	18.4	39.4	51.1

The needs most closely related to water resource developments are those associated with upstream watershed projects, drainage areas above potential storage reservoirs, and critical erosion areas. There is a future need for preparation of lands and onfarm facilities for drainage and irrigation.

96. Environmental factors. - The environmental factors associated with water and related land development programs deserve increased attention. Although existing programs have given consideration to environmental factors in site selection and in planning of the projects, much more insight regarding intangible values is needed to fully define the relative merits of alternatives in project formulation.

Certain reaches of the basin streams are worthy of preservation in a natural state for future generations to study and enjoy. However, water

resource development can enhance some of these areas by providing flood protection and increasing sustained flows. Several sites considered of national significance are parts of Blue River in Indiana, Cheat and Greenbriar in West Virginia, Cumberland in Kentucky and Tennessee, Little Wabash in Illinois, and Youghiogheny in Maryland and Pennsylvania. In addition, there are numerous locations which could be incorporated into State and local parks. Detailed studies are required to define the programs and locate the extent of areas worthy of inclusion. Historic, archeological, and cultural sites also need attention focused on them so that they can be incorporated in the programs. Indians played an important role in the early explorations and development of the Ohio Basin, and many burial and village sites are worthy of public sponsorship for their conservation. Some early forts, villages, and canals have been restored, but much more can be done. The history of man's impact on the development of the basin is also worthy of preservation.

Water resource development impacts on environmental values should be a basic consideration in project planning and design. On the other hand, many environmental pressures, such as urban sprawl, problems of solid waste disposal, and overuse of land resources often have effects on water resource projects. Basinwide studies to define environmental values would be helpful in identifying the areas which need attention most. Preservation of potential reservoir sites to prevent encroachment and preemption is also urgently needed. Many environmental considerations are a factor of resource availability as related to water resource development rather than a program development need.

SECTION V

WATER AND RELATED LAND RESOURCE AVAILABILITY

97. The Ohio Basin has a humid continental climate and is an area of general annual water surplus. Precipitation at rain gages in the basin has ranged from 20 to 72 inches per year; however, the extremes may be even greater. Maximum monthly precipitation has been about 9 inches or more at all locations in the basin with extremes of nearly 20 inches in the southwest portion. The minimum monthly precipitation has been less than half an inch and at many locations has been only a trace. Normally, seasonal variation in average precipitation is moderate with minimums occurring during the fall. Nevertheless, there is pronounced variation in runoff. The monthly winter and spring streamflows may be over 100 times higher than the low flow of an early fall month. Ground water levels are generally highest in the early spring and recede on much the same seasonal pattern as streamflows, although minimums may lag behind lowest streamflows by a few days to several weeks.

Most of the desirable land in the basin is in cultivation or other productive uses. The more rugged lands and areas near streams are forested or in brush. Nearly 50 percent of the Ohio Basin study region is cropland and pasture, and 40 percent is wooded. Somewhat more than 1 percent is covered by water.

Remaining reservoir sites in the basin, large enough for major water control, are limited in number and storage capacity because of physical features, such as topography and geology, or developments of man. Potential large reservoir sites are available on southern and eastern tributaries, but large storage sites are sparse in areas of most need, near the concentrated population centers in the northern part of the basin.

98. Surface water. - Annual streamflow of Ohio River tributaries has averaged in the years of record from 11 to 23 inches of equivalent runoff. In general, runoff is greatest in the eastern and southern parts of the basin and lowest in the northwestern glaciated areas. The volume of streamflow is generally greatest from January through April with normally about half of the annual flow occurring in this 4-month period.

Minimum annual runoff during the period from 1941 to 1954 has ranged from 2.6 inches in the Wabash Basin to 16 inches in the Allegheny Basin. As would be expected, minimum runoff on the smaller tributaries within subbasins has been much less. For example, the Little Wabash had streamflow equivalent to only six-tenths of an inch of runoff in 1931. Dry period streamflow is dependent on ground water discharge to the stream from seeps and springs. Generally, low streamflow occurring less than 10 percent of the time, is mostly from ground water. Where aquifers are poor yielders, many small streams go dry during the summer and fall.

Extremely high flows on tributary streams are often caused by thunderstorms and are generally of short duration. Occasionally, widespread storms with several days of rain cause floods on both tributaries and the Ohio River at the same time. Streamflows above flood stage on the Ohio River may last for weeks. On the Ohio River, the maximum monthly flow of record has equaled about one-half of the average annual discharge. The following extreme monthly and average June runoff for selected tributaries are representative of the Ohio Basin:

Tributary Basin	Runoff, Equivalent to Inches in Depth Over the Drainage Area and Month of Occurrence: Maximum	June Average	Minimum
Allegheny-Monongahela	8.7 Mar	1.2	0.10 Oct
Kanawha	6.7 Mar	1.0	.15 Oct
Scioto	8.7 Jan	.8	.06 Oct
Green	11.8 Jan	.9	.05 Oct
Wabash	7.7 Jan	1.0	.09 Dec

The average annual runoff from the Ohio River drainage upstream of Metropolis, Ill., near the junction with the Mississippi River (includes Tennessee River runoff), is equivalent to 17.3 inches or 187 million acre-feet. This corresponds to a discharge of 23 billion gallons per day throughout the year. During the greatest recorded flood (January-February 1937), the peak flow at Metropolis was 1,850,000 cubic feet per second. The lowest discharge at the same point is estimated to have been about 10,000 c.f.s. during the 1928-1930 drought.

Table 22 presents average annual discharges, instantaneous extremes, and the chances of occurrence of floods and low flows at selected key locations in the Ohio River Basin. "Appendix C: Hydrology" gives details of surface water availability throughout the Ohio Basin.

99. In general, natural surface waters in the Ohio Basin are of good quality. Dissolved solids vary from less than 100 parts per million (p.p.m.) to somewhat over 1,000 p.p.m. Acidity, chlorides, and organic wastes, largely a result of man-caused pollution, create the major quality problems. Hardness varies roughly from 100 to 500 p.p.m. (soft to moderately hard), dependent on location, being highest in the glaciated areas of Ohio, Indiana, and Illinois. Sulfates in some areas are over 500 p.p.m., but are generally below 250 p.p.m., the maximum concentration recommended by U.S. Public Health Service standards for finished drinking water. The chemical

concentration in surface water increases during periods of low flow due to a greater chemical content in ground water discharges. During the higher discharge months, chemical content generally declines, but turbidity rises. Purification treatment of surface water which reduces turbidity and kills organisms harmful to health is necessary for municipal use.

100. Ground water. - The ground water resources of the Ohio River Basin provide a considerable potential for satisfying water supply demands. Ground water is available from extensive glacial-drift aquifers throughout the northwestern third of the basin. The valleys of the following listed rivers, as well as those of many of their tributaries, are filled with permeable glaciofluvial sediments capable of yielding large quantities of water: the Allegheny, Muskingum, Hocking, Scioto, Little Miami, Great Miami, and Wabash. The areas of greatest potential for development of bedrock sources for ground water supply are those underlain by Mississippian and Pennsylvanian sandstones in parts of the Allegheny, Beaver, Muskingum, Monongahela, Kanawha, Guyandotte, and Big Sandy River Basins; and those underlain by Silurian and Devonian limestones in the Scioto, Great Miami, and Wabash Basins. In good aquifer areas, ground water pumpage could be used to augment dry-weather streamflow or otherwise reduce demands on the surface source.

The mineral content of ground water is generally higher than that of surface water. In those areas of the basin which are underlain by sandstones of Pennsylvanian and Permian Age, chloride content tends to increase with depth and, hence, poses quality problems in some areas. Significant problems of excessive chloride exist in several areas in the Allegheny, Scioto, Wabash, and Green River Basins where oil-formation brines have encroached into overlying aquifers or have entered streams. Where limestones and dolomites comprise important aquifers, especially in the Scioto, Great Miami, Licking, Kentucky, and Wabash subbasins, problems associated with excessive mineral concentrations and hardness are encountered. High iron content is common throughout the basin.

Ground water temperatures vary from 48° to 60° F. Water temperatures generally approximate the annual average air temperatures and, hence, are somewhat lower in the northern than in the southern part of the basin. Quality and availability characteristics of water from principal aquifers in the various subbasins are given in table 23.

Ground water availability in bedrock and in glacial drift and alluvial aquifers is shown in figures 21 and 22. Details are given in "Appendix E: Ground Water."

101. Land resources. - The basin lands are an important asset to its economic development. Lands are sufficient to serve most of the projected local economy. Improved farming methods, land treatment measures,

supplemental water for crops during droughts, drainage, as well as forest and soil conservation management can provide a large share of the basin's portion of the projected national needs for food and fiber products. Competition for lands will be increasingly great for agriculture, urban development, industrial sites (especially on navigable waterways), reservoir sites for water control storage, recreation areas, and wildlife habitat. Efficient land use in all areas will be required to meet the economic needs. Long-range land use and management plans are essential for the best use of land in providing for the demands of the future.

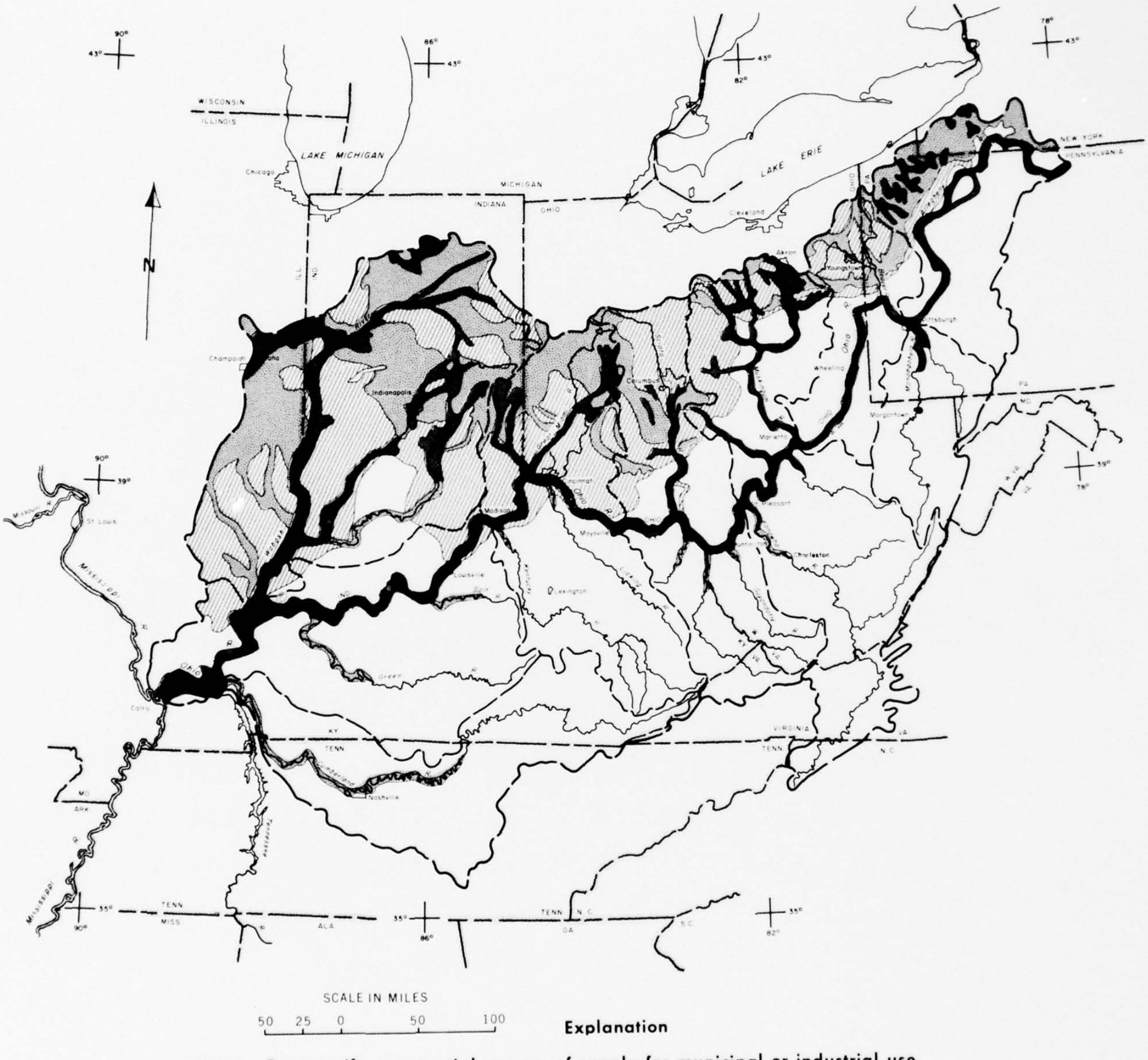
Ohio Basin Study Area Major Land Uses - 1960

	Acres (In Millions)	Percent of Total
Cropland	34.2	33
Pasture	16.4	15
Woodland	40.8	39
Urban and Built-Up	4.9	5
Other	7.0	7
Water Areas	1.1	1
Total	104.4	100

Of the woodland areas, 92 percent are on farms and in miscellaneous private ownership, 5 percent are in national forests, and 3 percent in other public ownership.

As production of food and fiber increases, shifts in the present land use will be required. Land treatment measures will be essential over a large part of the Ohio Basin study region.

102. Effects of going programs on resource development potentials. - Existing programs of water and related land resource development have utilized a considerable portion of the total water resource potential of the basin. However, with the exception of a few subbasins, the remaining resource potentials in the Ohio Basin are sufficient to offer a choice of alternative solutions to meet foreseeable needs. The resources previously selected for development were those that furnished the best solutions to problems under consideration at the time. For those instances where control of flows by reservoirs was required, project and program formulations were based on consideration of Ohio River tributary and main stem problems. Many of the best remaining reservoir sites that would fit into a basinwide system for streamflow control have been preempted by urban development, highways, railroads, or other enterprises which would be impracticable or very costly to relocate. Remaining available sites generally have less potential storage volume and yield than reservoirs already constructed. Therefore, solutions to Ohio River and tributary problems will require additional



Explanation

Best aquifers: potential sources of supply for municipal or industrial use. Individual wells commonly yield 100 or more gpm.

Sources of supply for small municipalities or industries. Individual wells commonly yield 20 to 100 gpm.

Sources of supply for domestic use. Individual wells commonly yield less than 20 gpm

Unglaciated area: unconsolidated rock aquifers not present.

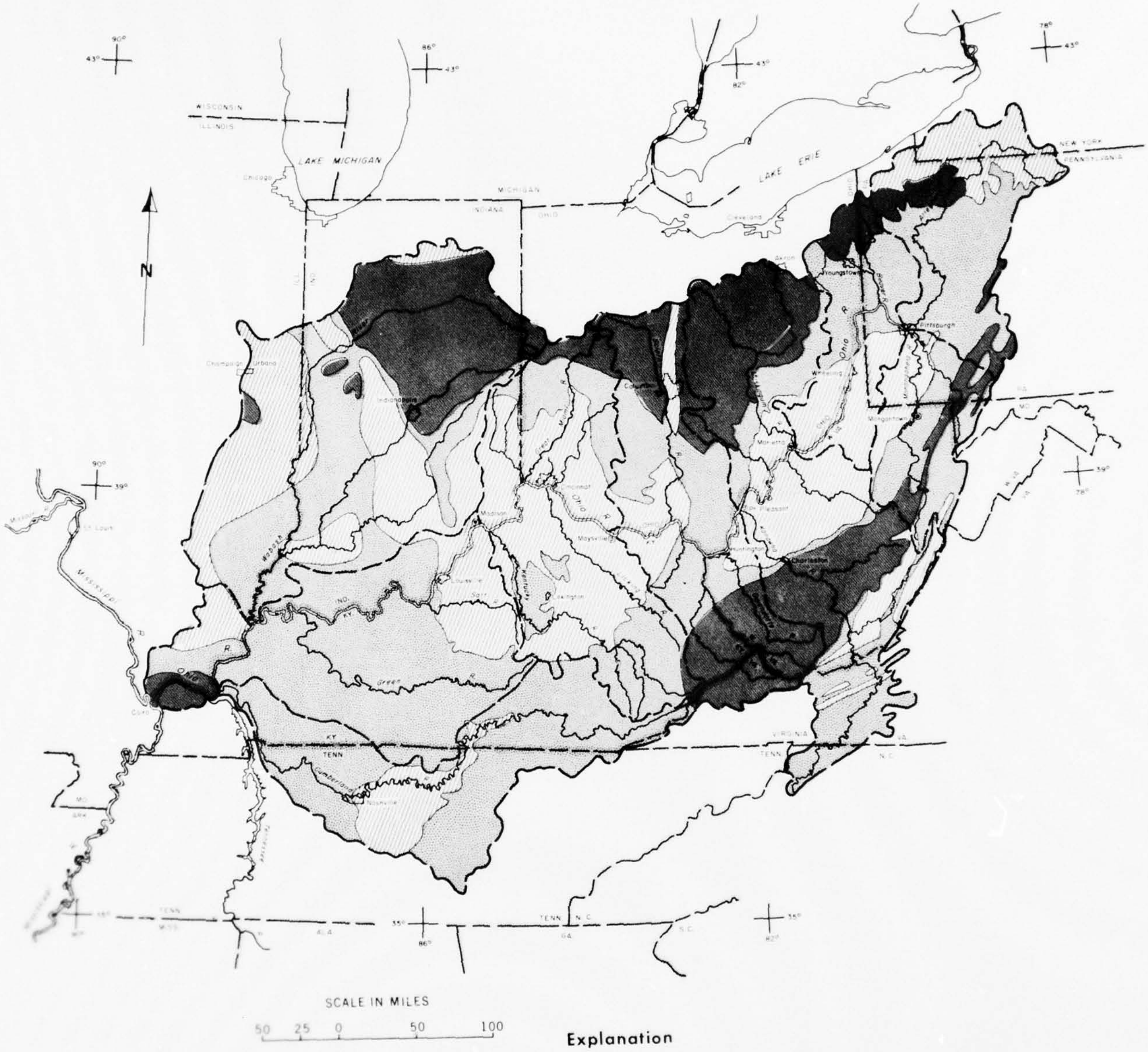
Adapted from maps of the U.S. Geological Survey, Appendix E, Ground Water distribution and potential in the Ohio River Basin.

OHIO RIVER BASIN COMPREHENSIVE SURVEY

SOURCE OF GROUND WATER IN BEDROCK FORMATIONS

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE 21



Explanation

Best aquifiers: potential sources of supply for municipal or industrial use. Individual wells commonly yield 100 or more gpm.

Sources of supply for small municipalities or industries. Individual wells commonly yield 20 to 100 gpm.

Sources of supply for domestic use. Individual wells commonly yield less than 20 gpm.

Adapted from maps of the U.S. Geological Survey, Appendix E, Ground Water distribution and potential in the Ohio River Basin.

OHIO RIVER BASIN COMPREHENSIVE SURVEY

SOURCE OF GROUND WATER IN UNCONSOLIDATED SEDIMENTS

CORPS OF ENGINEERS — OHIO RIVER DIVISION

APPENDIX K — FIGURE 22

reservoirs of a comparatively greater storage cost. Nevertheless, potential reservoir sites of reasonable cost in relation to needs remain in most Ohio River tributary basins. Solutions to many Ohio River problems may be furnished by a choice of various combinations among remaining alternative reservoirs in the same or different tributary basins. In areas which lack suitable remaining reservoir sites, alternative developments such as local flood protection works, ground water development, importation of water, and other measures will be required.

103. Net availability of resources. - The unused and underused water and related land resources available in the Ohio River Basin, if well managed and properly developed and used, are adequate to serve the projected needs far beyond those of the study period to 2020. However, either the economic activities must be geographically patterned in accordance with the resource availability, or alternative measures must be undertaken. The minimum annual surface water runoff from the Ohio River Basin study region, as reflected by streamflow above the mouth of the Tennessee River, is estimated at 5 inches of runoff or 43 million acre-feet. To assure a supply approaching the average annual runoff of 187 million acre-feet per year for the entire Ohio River drainage would require well over 400 million acre-feet of storage space. Of the total Ohio River watershed runoff, 46 million acre-feet are contributed by the Tennessee River, which is presently controlled to a high degree by 15 million acre-feet of reservoir storage. About 100 million acre-feet of storage would be required in the Ohio River Basin study area to assure a sustained Ohio River flow of 80 percent of the area's annual average runoff of 141 million acre-feet.

104. There are 30 million acre-feet of storage in the 1965 going program for the Ohio River study region. About 90 percent is in reservoirs of major size. The remainder is in unregulated detention structures or small water supply reservoirs.

The 1965 going program provides 17 million acre-feet of storage effective in controlling Ohio River floods. The amount of additional strategically located storage required to control the Ohio River Standard Project Flood (a rare flood of the largest magnitude that might reasonably be expected to occur) to the stage of the maximum flood of record, is about 26 million acre-feet. Development of this storage would be very effective in control of flows in the tributaries below each reservoir. It is estimated that to fully control the Ohio River Standard Project Flood by reducing it to below damage stage, would require nearly 200 million acre-feet of storage.

There are undeveloped reservoir sites that could provide about 120 million acre-feet of storage space for effective control of high and low flows. Of this total, only about 60 million acre-feet appear feasible for construction, because a use of the remaining storage potential would

entail costly relocation of economic development or, in some cases, adverse effects on rare ecological, historic, natural science, or other enviromental values that should be preserved. An inventory of upstream watershed areas indicated availability of 6,200 detention structure sites with an additional capacity of 27 million acre-feet of storage. Of these, 2,930 sites and 5 million acre-feet of storage were considered potentially feasible as part of watershed projects.

Identified potentially feasible storage reservoirs and upstream watershed projects with their size and surface areas are given in tables 24 and 25.

Farm ponds also play a significant role in the rural areas in that they are generally used for watering livestock, firefighting, and, in some areas, supplementing domestic supplies. They also add to the attractiveness of the landscape and often are stocked with fish or waterfowl. There are an estimated 1.5 million sites suitable for farm pond development. They would have no significant effect on the streamflow control requirements and provisions evaluated in this study.

The evaporation rate from May to October is about 2 feet in depth over water surfaces or a loss of a million acre-feet of water per year from existing impoundments. While the magnitude of this loss is small in comparison with the total average basin runoff, it significantly reduces the yield from reservoir storage during extended droughts.

Sixty-seven percent of public water supply facilities use ground water and pump 27 percent of the water used for municipal supplies. Most of the rural domestic use comes from ground water. The buried glacial valleys are particularly good sources of ground water; however, additional exploration is necessary to define the expected yields from wells. Large withdrawals can be obtained from wells located in the alluvial material along streams where drawdown will induce recharge of the aquifers. Best bedrock aquifers are located in the upland areas of the northern tributary subbasins of the Allegheny, Beaver, Scioto, Great Miami, and Wabash Rivers and in parts of the headwater areas of the Monongahela, Kanawha, and Guyandotte-Big Sandy subbasins.

Ground water reserves, with the exception of some local areas of high pumpage, are relatively unaffected by excessive drawdown. Wells will continue to serve much of the rural area and many of the smaller towns and industries.

Undeveloped conventional hydroelectrical resources at potentially feasible reservoirs and identified pumped-storage project sites have a potential for an installed capacity of about 7.6 million kilowatts. These resources are listed in table 28. In addition, favorable site terrain is available throughout the Ohio Basin for 30 to 40 million kilowatts of additional pumped-storage capacity.

WATER AND RELATED LAND RESOURCE AVAILABILITY

Available resources are adequate to serve navigation facility development needs for the Ohio River and present tributary waterways. These navigable streams can be further improved by increasing depth and width and by shortening the sailing line. Resources are available for extending the waterway system on tributaries, including new connecting waterways between the Ohio River system and the Great Lakes.

105. The agricultural land resource may appear to be underutilized due to the considerable pasture acreage and idle land. However, much of this land is not well adapted to crops. Much of the pastureland is hilly, has poor soil, is located in flood plains, or is unavailable for crops for other reasons. There are 12.1 million acres of land which have been drained, and 91,000 acres have been irrigated. Soil resources are such that an additional 4 million acres have an economical potential for drainage, and 1.3 million acres, for irrigation. About 40 percent of the basin is forest land, and nearly all of this is capable of producing industrial wood. Yet, less than half of this land is planted with growing stock trees. In many areas, cropland is interspersed with timber growth which is generally not logged. In general, the land resources are adequate to serve the economic needs if properly developed and efficiently managed and used.

106. The available resource facilities accommodated in 1965 about 220 million outdoor recreation-days, about 40 percent of which were spent at public water and related land developments. It is estimated that an additional 44 million man-days were spent fishing and hunting. Projected land area requirements to serve 2020 recreation needs range from less than 2 million acres to nearly 9 million acres, dependent upon intensity of development and use. In a similar manner, water area needs vary from about 600,000 to 9 million acres. The basin's water and land resources have the capability of providing for the needs, but the geographic distribution of potential developments does not always coincide with the location of demands.

107. The Ohio Basin study area has about 46,000 miles of fishable streams, 14,000 acres of natural lakes, 700,000 acres of impounded waters, and 372,000 surface acres of water behind navigation structures. The water and land resources, combined with additional impoundments, facilities, and management, are adequate to support high-quality fishing and hunting opportunities.

In 1960 the actual commercial fishery habitat was 191,000 acres of a total potential of 415,000 acres. Due to stream quality improvement, Ohio River navigation dam replacement programs, and additional storage reservoirs, the potential habitat is expected to increase to over 635,000 acres by 1980. The available resource, if properly managed, is adequate to meet future needs for fish.

SECTION VI

FORMULATION OF FRAMEWORK PLAN

108. The relationship of physiography, geology, and present economic development in the various study area subbasins plays an important role in the formulation of plans to satisfy the overall Ohio River Basin future demands for water resource and land developments. The Ohio River receives the flow from the Allegheny and Monongahela Rivers which drain the eastern portion of the basin; from seven major tributaries entering from the north and nine entering from the south; as well as from many minor tributaries. The smallest of the major tributaries has a drainage area of about 1,200 square miles. The headwaters above Pittsburgh, Pa., contribute more than 12 percent of the total Ohio River flow at its mouth. Below the junction with the Kanawha River, 26 percent of the total drainage area has contributed to the Ohio River. About halfway down the Ohio River, at Cincinnati, Ohio, the drainage area is almost one-half of the study area and 38 percent of the entire Ohio River watershed. The Wabash and Cumberland subbasins make up 31 percent of the study area. Including the Tennessee River Basin these jointly make up 45 percent of the total Ohio River drainage area, but their combined runoff affects only the lower 47 miles of the Ohio River.

Concentrations of people and industry create the major demands for water supply, navigation, flood control, electric power, low flow regulation, recreation, fishing, hunting, and many other resource uses. The largest population centers are Pittsburgh, Pa.; Youngstown, Columbus, and Dayton-Middletown-Cincinnati, Ohio; Louisville and Lexington-Frankfort, Ky.; Charleston and Huntington, W. Va.; Indianapolis and Evansville, Ind.; and Nashville, Tenn. In general, these are also the areas with the greatest problems.

Because of the large study area, 163,000 square miles, the distribution of the resource availability in relation to demands is one of the most important considerations in the basin-wide planning process. A large portion of the water resource development problems in the basin are due to the intensive economic development along the banks of the Ohio River and major tributaries and the large variability of stage heights and flows. Each subbasin has individualistic water and related land problems primarily related to its particular topography or economic activity. Nevertheless these various subbasins often act as a coordinated group particularly as to their effect on Ohio River flows. Therefore a system or network analysis was required to assure that pertinent interrelationships and proper "feed back" were brought into the total basin planning process.

109. The most critical water resource problems in both the tributary drainage areas and along the Ohio River are caused by deficiencies or excesses of streamflow, by impaired water quality, and by flood plain and other land utilization. Solutions of major basin-wide problems are (a) developing sufficient ground water and effective reservoir storage to

provide the water supply requirements, (b) maintaining stream quality, particularly in the principal watercourses of subbasins located on the northern side of the Ohio River, in the Kanawha River, and the Ohio River, and (c) controlling runoff, erosion and floodflows.

Recreation, fishing and hunting developments for the period to 1980 can be provided within reasonable driving distance of most demand areas but are not necessarily within the same subbasin. On the other hand the total demands on the basins lands for agriculture, urban development, recreation and other uses may result in a possible shortage of 6 million acres by 2020. Consequently greater multi-use of lands will be required especially for forests, agriculture, recreation, fishing and hunting. As the resources are being developed there will be opportunity for trade-off between the various sub-basins in planning for the use of lands considered suitable for irrigation and drainage. Widespread basin areas are in need of land treatment and management to reduce erosion and make farming more productive. The smaller urban developments in the upstream watersheds, although not having the same concentrated problems as large cities, need flood control, water supply, low flow regulation, and provisions for recreation, fishing and hunting.

110. Extensive transportation systems join the many markets and producing areas. The rivers carry large volumes of freight on their navigable reaches. Electricity for use in the basin and export outside the region is generated where a balance of fuel for energy, water for cooling, and length of transmission lines to markets can give the greatest economic return. Nevertheless within the Ohio Basin this allows a relatively large amount of flexibility as regards plant location. Thermal pollution is, however, becoming a major factor which must be considered.

Total solution of problems directly related to water requires the effective support of programs in addition to the water resources development program formulated herein. These supporting measures have been discussed in relation to each of the items in the framework plan, but it is recognized that alternatives not presently foreseen may need to be considered as elements of the program as it is being implemented.

By the year 2020, there will be a withdrawal need for water of over 95 billion gpd, of which over 90 percent would come directly from normal and storage supplemented streamflows and about 4 percent from groundwater. The remainder would be supplied directly from farm ponds and upstream reservoirs. Large portions of livestock and irrigation water, and some municipal and industrial needs will be provided by wells. It was estimated that by 1980 an additional 525 mgd for all purposes will come from ground water and by 2020 this would increase to nearly 2,500 mgd. Surface waters will be impounded during high flow periods for release as needed for water supply. Storage releases to maintain sufficient flow for satisfactory stream quality will meet some requirements for water supply. After adequate treatment at each withdrawal location, the water is returned to the stream and reused for other purposes on its way downstream.

FORMULATION OF FRAMEWORK PLAN

111. Damaging floods are still major problems throughout most of the region. Much has been done to protect major urban centers along principal tributaries and the Ohio from frequent flooding and in some cases, particularly along the Ohio River, from historic floods of record. However, in view of the apparent catastrophic nature of a flood occurrence in excess of protection stages along the Ohio River, a special study was made to establish a Standard Project Flood (SPF) for the Ohio River. The SPF has critical flood volumes and peak discharges resulting from the most severe combination of meterological and hydrological conditions that can be foreseen as reasonably probable chance of occurrence in the region. The sum of the SPF's for the tributaries, because of greater storm severity and runoff conditions is considered greater than the SPF for the Ohio River. Regulation of major tributary floods would control to a great degree the Ohio River SPF.

The Ohio River SPF is much greater than any historic flood and would be an exceedingly rare occurrence. While the control of the SPFs on the Ohio River and in each tributary may be logical flood control goals, experience has shown that a high degree of control of such floods is seldom economically feasible except for local protection works at concentrated damage centers. Thus, in addition to practical levels of floodwater storage and local protection works much reliance must be placed also on the effectiveness of flood forecasting and warning services and on flood plain management to minimize flood losses.

112. Mine drainage and oil field wastes problem areas are defined in the study. However, detailed corrective measures were not analyzed. The magnitude of the problem of mine drainage is estimated to exceed 2.5 million acid tons in calcium carbonate equivalent annually. Based on past and projected coal production, this figure could rise to seven million tons per year by 2020 if historical mining practices are continued. A detailed abatement program study of the mine drainage problems in the Monongahela Subbasin is now underway and should provide a basis for determining required measures for mine drainage control within the Ohio River Basin.

Since, water and related land resources in the Ohio River Basin are generally sufficient to meet the aggregated needs to 2020 and beyond, water resource development solutions are related primarily to adjusting seasonal and geographic disparities between the timing and location of requirements and of resource availability. To achieve optimum effectiveness of water resources development, other programs, beyond the current limits of data and practicality, must eventually solve unique water quality problems created by mine drainage, certain industrial wastes, and pesticides.

FORMULATION PROCEDURES

113. The plan formulation procedures involved (a) the identity and measurement of projected needs, (b) the determination of water and related land resources potentials, (c) the definition of a general method

of solution, (d) estimates of the magnitude and cost of needed development programs, and (e) outline of initial steps required to implement the programs. To differentiate between short- and long-term goals, time periods to 1980 and 2020 were selected for use in the development program formulation.

Requirements for products and services, discussed in section IV, were weighed as to how and to what extent experience in the basin indicated they could be satisfied by water and related land resource development. Water and related land resources availability, summarized in section V, were evaluated and compared with the requirements. Based on these studies, past experience, and the knowledge of planners familiar with the area, a determination was then made as to the best means of satisfying the needs. From these analyses, the framework plan was formulated.

Both requirements and resources were assessed largely on generalized data adjusted to facilitate comparability among subbasins and various programs. Elements of need and available resource were examined in turn from the headwaters to the mouth of the Ohio River. Alternative solutions were considered for each problem. The results obtained are believed sufficiently accurate to serve as a general guide to future actions concerning the location, nature, and timing of water and related land resource developments. However, specific project formulation and feasibility studies, being beyond the scope of framework studies, were not undertaken and the values presented herein should be considered as of reconnaissance scope rather than absolute evaluations for individual problems and projects.

114. Water withdrawal needs were determined on a broad regional basis. An approximation, based on general practice in the region, was made of the amount which would be satisfied by ground water, stream flow or storage developments. It was assumed that cities on the larger tributaries would use stream flow unless other sources were presently being used. Ground water was assumed to be the most likely means of providing most of the rural water supplies and many of the small to moderate quantities needed locally. Where ground water is currently being used and the geology indicates additional supplies are available it was assumed future withdrawals within the limits of indicated safe yields would come from this source.

A factor was developed for each sub-basin to translate net withdrawal needs into storage requirements. To prevent double counting of storage needs it was assumed that water made available by flow supplementation for water quality control could be used for withdrawal needs and then returned to the stream. Consumptive losses would be made up by additional storage to assure adequate stream flow for quality control and other uses.

115. Stream flow requirements for residual organic waste assimilation was determined by the Federal Water Pollution Control Administration for strategic point locations. The study assumes 85 percent or more of the organic wastes will be removed by secondary treatment. Without advanced

treatment, diversion to a larger stream for assimilation, or flow supplementation, these residual wastes after secondary treatment may cause serious pollution problems. Where storage sites are available and storage-yield relationships appeared efficient it was assumed that low flow supplementation in addition to secondary waste treatment would be a practical means of maintaining instream water quality. There are a number of locations in the Ohio Basin, particularly on streams with small drainage areas, where it is obvious that sufficient stream flow cannot be provided. In these cases it is assumed advanced treatment of wastes or diversion of effluent to a larger stream would be the most likely solution. A "breakthrough" in cheaper advanced waste treatment could of course reduce the need for flow supplementation. However the total stream regimen must be carefully reconsidered as increased flows also serve water supply withdrawals, recreation, fish and wildlife, navigation or general aesthetics.

Since flow augmentation releases required at upstream locations for water supply or water quality control are reused for many purposes as they pass downstream it is not possible to make an accurate determination of the amount of storage used for each purpose beyond the first use. As water supply, which is largely returned to the stream, and flow augmentation for water quality control are provided in tributaries the accumulated flows may be sufficient for meeting remaining downstream needs without additional storage releases. The make-up of consumptive water use was assigned to withdrawal storage. Therefore as this need increases, the ratio of water quality to withdrawal storage changes as the plan is implemented. Future policy may require modification to recognize the changing multiple-use aspects, costs and benefits of a unit of stream flow.

116. Critical periods for streamflow supplementation for water quality improvement are usually in July and August because of increased water temperature and increased biological activity. The flow required to provide sufficient oxygen to assimilate a given amount of waste during these warm months is generally about twice that required in January. Lowest streamflows generally occur in September and October. Because of these factors the need for flow supplementation is greatest from July through October. Reservoir storage volumes have been determined by taking into consideration the seasonal variations of flow needs, recorded streamflows, and the yield required to sustain streamflows adequate to meet withdrawal demands by municipalities, agriculture, industry, and for other purposes. It was assumed that thermal electric generating plants after 1980 will use primarily the evaporative cooling method, with consumptive losses replenished from storage or wells.

Because of multiple-purpose reservoir use and the widespread effects of storage regulation on streamflows in downstream river reaches, system analysis of basic problems and solutions were made by first considering each subbasin as an independent system. Data available from previous studies were reviewed, and pertinent, previously defined problem solutions were made a part of the framework plan. Flood control, water withdrawals, consumptive use, return flows, and reuse were taken into account in determining storage requirements.

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117. The subbasin systems were then analyzed with regard to meeting needs along the Ohio River. The additional amounts of storage required for Ohio River flood and low flow control were apportioned to the various subbasins on the basis of the relationship of reservoir potentials to the problem areas. This procedure recognizes that the provision of storage in subbasins will benefit all locations downstream of the reservoir site and much of this storage is needed not only for control of Ohio River flooding, but also for reduction of flood crests on tributaries. These tributary storage potentials were also analyzed as their joint-use capability in satisfying needs for low flow supplementation and for satisfying the demands for recreation, fish and wildlife enhancement, and other uses. The flood detention storage structures with ungated flood outlets and limited storage capacities are not considered effective for Ohio River flood control. While optimum storage efficiency for the control of Ohio River flooding may require specific storage in tributary subbasins, there remains, in most cases, opportunity for selection of alternative protection measures or site locations.

118. Upstream watershed projects provide reductions of flood peaks in upstream drainage areas and are effective in reducing erosion. Also, these sites provide opportunities for storage space for water for irrigation, recreation, and fish and wildlife, as well as for water supply and water quality control.

Channel improvement, local protection projects and non-structural measures such as flood forecasting, flood insurance, flood plain regulation and flood proofing are a part of the overall plan. The locations and geographic areas of interest for these features were selected from detailed studies available in Corps of Engineers Districts, Soil Conservation Services offices and state reports.

After each subbasin's needs were analyzed on a systems basis by working downstream, the water withdrawal and flow supplementation storage needs were reviewed in context of the completed analysis. Although it is difficult to allocate storage without detailed analysis, the percentage relationship of water quality and water supply storage in the framework plan are believed in the correct order of magnitude. Subbasins ratios varied but for the Ohio Basin's 1980 needs about 65 percent of the storage for later release was for water quality control and 35 percent for water supply. By 2020 the storage would be about half and half for these purposes.

In addition to those reservoir and detention structure sites selected from available agency inventories as being at feasible locations for providing a part of the needs, other sites will be required. From topographic and geologic data and a general knowledge of the area a determination was made as to whether additional storage would be available to fulfill the needs. These are given in the table on VI-18 as additional storage required.

FORMULATION OF FRAMEWORK PLAN

119. The analysis of navigation was initiated by establishing the need for water transport of bulk commodities based on past experiences in correlation with projected economic growth of the areas contributing to waterborne freight on the existing system. The assessment included an evaluation of the physical capability of the 1965 program. Potential extensions to the system were predicated on the same relationships, or on recently completed studies such as those of interconnection between the Ohio River navigation system and the Great Lakes.

Hydropower locations on which inventory data were available were assumed as part of the program to 1980. The analysis of hydroelectric power, after 1980, and commercial fishing was summarized on a basin-wide basis since the location of future developments for these purposes are not necessarily related to a particular subbasin demand.

The net requirements for sport fishing and hunting reflect only the additional resource development program required. Approximations were made as to the recreation, fishing and hunting, which would be satisfied at the water resources developments and included in the program. These were based on general recreation day-water area relationships as developed from data in Appendix F, G, and H, and Corps of Engineers operational statistics.

120. Development and use of the water and related land resources have direct effects upon the physical environment of the region. In the planning processes the environmental factors are of concern in formulating a development plan responsive to environmental quality goals and in detailed project planning to assure that the impacts of the project on the local environment are fully considered. The former is the area of concern to framework planning. However, in the case of the Ohio study the definition of environmental quality goals was virtually impossible, particularly, in view of the lateness in the study when environmental quality was promoted as a basic planning objective. In any event, the definition of an environmental quality goal for this region is complicated by the existence of environmental factors stemming from extensive present development and use of the water and related land resources. General areas of scenic or historical interest in the region have been identified and are referred to in discussions and tables in attachments A and C. The effects of a particular project on the local physical and social environment are matters that require detailed treatment in future detailed project planning.

121. The overall Ohio River Basin framework program was formulated by integrating subbasin plans into a regional system for controlling high and low stream flows and incorporating into the overall program, measures for utilizing potentials created by elements of the control system and for satisfying or ameliorating needs left unsatisfied by such systems. The procedures followed in subbasin assessments and plan formulation are described below. A regional hydrologic system analysis was used to integrate the flow control features of the subbasin plans into a regional

system. Feed-back analyses were made to assure adequate dimension in the subbasin plans to meet flow requirements at problem areas along the Ohio River. By integrating in the regional program all features of the subbasin plans including those for recreation, fish and wildlife, erosion control, and other purposes, a framework program was defined that would satisfy, to varying degrees, the water related needs of the region. Since the program thus defined failed to meet all the needs, non-structural measures, and measures in the private sector, to satisfy the remaining unsatisfied needs were recognized as important appurtenances to the overall framework program. Flood plain management and private outdoor recreation facilities are examples of the type of measures in this general supporting category. However, because of the lack of techniques for assessing the effectiveness of such programs without the benefit of detail studies, and in the absence of any guidance as to the relationship, to the framework program, of those levels of outdoor recreation and land management that have no significant association with development of the water resources, the non-structural and private measures were not probed in depth for this study.

SUBREGIONAL ANALYSIS

122. System analysis of basic problems and solutions were made by considering each subbasin as an independent system, bearing in mind that storage regulation of streamflows has widespread effects on downstream river reaches. A subregional analysis is presented in Attachment A for each hydrologic subbasin. The subbasin analysis evolved around the following steps:

1. Using basic input data from the various appendices, a reference base year amount and projected increases to years 1980 and 2020 were determined for the major subbasins for water supply demands in million gallons per day for municipal and industrial purposes, electric power cooling, rural communities, rural domestic and livestock, and irrigation purposes; organic stream loadings expressed in population equivalents for treated waste effluents requiring stream assimilation; average annual flood damages in dollars; annual waterway freight movement in ton-miles; annual general outdoor demands in recreation days; annual sport fishing and hunting demands in angler days and hunter days, respectively; and lands, expressed in acres requiring treatment and management, drainage, and irrigation.

2. As developed in Appendix D, Water Supply and Water Pollution Control, the residual waste loadings to the stream after secondary treatment were translated into flow requirements at point locations in each subbasin. Water supply withdrawals were developed also in Appendix D for 62 minor economic subareas as developed from a disaggregation of the 19 economic subregions. These data were used to define water quality and water supply problem areas.

3. Reservoir capacity requirements were established for water quality, water supply and flood control using generalized flow-storage yield curves for each major subbasin. The determination of reservoir storage requirements depends on the location of storage sites, location of problem areas, return flows and joint uses, and, accordingly, required a systems operation analysis. As an aid to this analysis, schematics were prepared for each subbasin showing stream systems, problem areas requiring streamflow control, projects in the going development program, and identified potential projects. Reservoir capacity requirements for water supply and water quality were determined taking into account available ground water and streamflow. Flood control storage requirements reflect an effective comprehensive flood control and damage prevention program including flood plain land use regulation and other non-structural flood control measures. Final adjustment of reservoir capacity requirements was made for joint storage use. Storage requirements in addition to these provided at identified sites were accounted for to the extent that resources indicated storage was the most practical means of meeting unsatisfied water supply, water quality control, and flood control needs.

4. After solutions for flood control, water supply, and water quality problems were defined, their storage control components were evaluated for their potentiality in satisfying recreation, fishing, and hunting demands. Resources in excess of subbasin requirements were assessed for their availability to solve a demand in adjacent subbasins and the Ohio River subareas.

5. Reaches of the Ohio River together with the drainage areas of minor tributaries were also analyzed similar to the major tributary subbasins. Needs along the Ohio River were defined, and required resource developments were included in the program. If flow regulation needs in the subbasins are satisfied, sufficient flows will be available to adequately maintain water quality in the Ohio River.

6. Navigation facilities, hydroelectric power developments, flood control measures in addition to storage, lands requiring treatment and management, lands requiring drainage, and lands requiring irrigation, as developed in the other appendices, were then accounted for in the subbasin plans.

7. The capital costs for the framework program were determined by applying cost relationships for similar programs and geographic areas, as established in the appendices and from agency data. The elements of the basin-wide program for the year 2000 were obtained directly or by interpolation of study data presented in the supporting appendices.

Principal water supply, water quality, and flood problem areas, together with projects in the going program of development and those identified as potential future projects are shown on the various subbasin maps,

figure I in each subbasin summary, in attachment A. Summary data for projects in the going program are given in table 15 through 21. Potential identified projects are given in tables 24 through 28. Key data relating to problem areas are given in table 2 of the summaries and shown schematically in figure 2 of the subbasin analyses. The schematic diagram was used for general orientation in analyzing problems and needs and establishing development requirements for streamflow control. Subbasin summary table 3 gives an accounting of storage capacity required for streamflow control in addition to that provided in the going program. The amounts of storages designated for the various purposes are influenced by the order of study determination. They should reasonably represent the allocations of storages between flood control and low flow control for the subbasin but may have wide variances in the allocation between water supply and water quality control. The allocation between these low flow control items are highly influenced by project location, timing of development as related to urgency of needs, law and policy concerning cost allocation and repayment. Table 4 of each subbasin summary is an assessment of resource development requirements and initial investment capital costs associated with serving units of need by time periods to the year 1980 and the year 2020.

ALTERNATIVES

123. Alternatives were considered in each step of the study and throughout the plan formulation process. Choices were evaluated; but, since benefit-cost determinations are not a part of framework studies, many selections were based on approximations and the judgment of experienced planners familiar with the area. Each agency, in its studies and preparation of the appendices, considered the degree to which the needs should be fulfilled and the alternatives for solving the problems. Regional views have been incorporated into the framework plan by active participation of State agencies. Coordinating Committee meeting discussions and review comments on preliminary drafts of all agency reports have been incorporated into the planning process. As the detailed planning proceeds through the program implementation phases, all possible alternatives, some of which cannot now be foreseen, will have to be given detailed consideration as a basis for selecting at that time the best and most economical solution to a particular problem. Since economics and accepability will be dominant factors in assessing alternatives to arrive at final selection, the framework costs established herein should be considered as an order of magnitude rather than firm cost estimates. Furthermore, the flexibility inherent in a plan of framework scope should stand in good stead in arriving at such selection.

Flood control alternatives considered were reservoir storage; levees, floodwalls, and channel improvements; land treatment and management; flood plain management; flood forecasting and insurance; and continued endurance of a tolerable flood damage risk. These various means generally complement each other, rather than being competitive, and each shares in the prevention and reduction of flood damages.

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OHIO RIVER BASIN COMPREHENSIVE SURVEY. VOLUME XII. APPENDIX K. --ETC(U)

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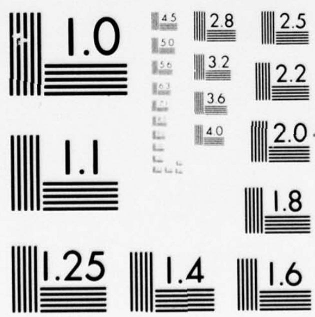


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

FORMULATION OF FRAMEWORK PLAN

124. Alternatives to serve water withdrawals needs were additional ground water development and surface water storage. Aquifer yields, water quality and development costs would determine the merits of the ground water alternative to surface water storage for specific problem areas. Suitability of aquifers for recharge and availability of good-quality recharge water are important potential alternatives to storage developments to serve as coordinated system components of large-scale water supplies. Future technological advances may eventually bring recirculation of treated waste effluents into the picture as an alternative water supply source.

Probably the most complex evaluations of alternatives deal with water quality control in streams. Criteria presented herein are essentially based on sufficient stream oxygen as measured by needs of aquatic life. However, there are considerable differences in views as to what those requirements are, especially as to the dissolved oxygen needs and acceptable water temperatures. During early stages of the study, 4 p.p.m. of dissolved oxygen in the stream was chosen as the water quality criteria for the Ohio River Basin Comprehensive Survey as a datum for comparing water quality needs. The Federal Water Quality Act of 1965 requires that the States set interstate stream standards. The long-range standards chosen are generally higher than 4 p.p.m. of dissolved oxygen, and, in addition, other quality parameters are defined. The higher standards would either create a demand for more efficient waste treatment than the 85-percent removal of BOD used as a general criteria in the Ohio Basin study or require additional water for flow supplementation and temperature control in the problem areas. Restrictions on industrial waste effluents including heat will also be a significant factor on streamflow requirements. Detailed analysis of each problem area will be required during program implementation to establish the most feasible solution.

125. In-stream aeration by mechanical means, such as injection of air or turbulence inducing mechanisms can increase the dissolved oxygen under certain conditions and may be a practical alternative to increased streamflow in some locations. However, effectiveness and cost have not been determined for large installations. Also, the effects on in-stream uses, stream environment and the aesthetics of the immediate area need careful consideration. For tertiary waste processes, treatment costs are estimated to be from 3 to 5 cents per 1,000 gallons, for a 10-million-gallon-per-day installation for foam separation, to somewhat less than a dollar for distillation. Storage in the Ohio Basin can be provided for $300 an acre-foot or less, in most instances. Over the life of the project this would be less than 2 cents per 1,000 gallons. Based on these estimates, it appears that in most of the problem areas streamflow augmentation by reservoir storage will be the economical means to assimilate organic waste residuals after secondary treatment. Also the augmented flow regenerates its oxygen levels on its way downstream after the dissolved oxygen has reached the lowest content, and therefore, can usually assist in solving other downstream quality problems. In addition, while stored, the water quality storage may serve recreation uses. At

some locations, especially in extreme head water areas, where storage sites are scarce or the water resource limited, the higher degree of waste treatment may be the only solution.

126. Although practical and economic water renovation techniques for general use are presently unavailable, future development of a physical-chemical separation process to remove dissolved salts and complex synthetic organic wastes which are unaffected by standard treatment may change the entire philosophy of water needs. Water can then be recycled and be independent of the continuous flow at a source. This might change the entire concept of waste treatment as it relates to stream flow. It is not believed that this type of development will affect the early storage needs of the basin although it will probably become more significant in the later part of the study period.

OHIO RIVER BASIN FRAMEWORK DEVELOPMENT PROGRAM

127. Timely implementation of the Ohio River Basin Development Program formulated herein will satisfy the foreseeable demands in goods and services which are best furnished by water and related land resources. The study demonstrates that broad, large-scale, Ohio River Basin demands for products and services of water resources development can be met in large part by a system of multiple-purpose impoundments and other structural and management measures. The study also shows that these measures must be supplemented by other resource developments and management programs to achieve an optimum basin-wide plan. The Department of Agriculture's studies of farming practices and the timber industry indicate a need for watershed management including land treatment and structural measures as essential elements of an upstream watershed program. Other studies show that land treatment and management, irrigation, drainage, recreation, hunting, and fishing should be developed within the concepts of the framework development program. Weather and streamflow forecasting, flood plain management and weather modification are needed to supplement structural measures for flood control. In addition to the program for development of water resources and related lands, other programs for recreation, enhancement of fish and wildlife and preservation of scenic areas will be important aspects of the total framework plan. Ancillary programs such as water and waste treatment plants, pumping stations, wells, etc., are needed to fully utilize the water resources made available by implementation of the plan.

STREAMFLOW CONTROL

128. The development program to year 2020 would reduce flood damages through storage, detention structures, local protection projects, land treatment and management and flood plain regulation. The plan provides for 33.4 million acre feet of storage in addition to the 17 million in the July 1965 program. Of this new construction 15.3 million acre feet is available in 161 identified major reservoir sites and 3.5 million is in 2,930 potential upstream watershed detention structures. The remaining

14.6 million acre feet are in sites still unidentified but believed available based on a review of available topographic and geology data for pertinent subbasin areas. The upstream detention storage sites generally complement the major reservoirs storage. The exact locations and possible alternative use of reservoirs must be determined in detailed planning.

Table 24 lists the identified potential reservoir sites and table 25 the upstream watershed projects together with pertinent data on the structures, channel improvement and other items. The plan includes 700 flood plain information studies as a basis for improved flood plain management. In addition, increased channel capacities, levees or flood walls are needed to solve local problems. The plan contains 95 major and 48 small local protection projects containing about 400 miles of levees and flood walls and about 88 miles of major channel improvement. These proposed projects are summarized by types and subbasins in Table 24A. The upstream watershed program includes 6,300 miles of rural channel rectification. Intensive land treatment and management can reduce erosion and retard runoff with some beneficial effects on flood stages in the smaller drainage areas. However, its effects on major tributary and Ohio River floods would not be significant. The plan includes land treatment and management on 29.2 million acres in upstream watersheds, above reservoirs and in critical areas. Another 22 million acres of land treatment and management is to be provided by affiliated land management programs.

129. Forty percent of the projected potential 2020 flood damages are in upstream areas and sixty percent in downstream areas. The plan will reduce the total estimated 2020 potential damages of $296 million to a total residual for the region of about $70 million average annual damages. Structures will prevent $167 million average annual damages and $59 million will be prevented by the nonstructural measures. As might be expected the greatest damage prevention per acre is in the more industrialized stream reaches. Approximately one-sixth of the Ohio Basin's average annual 2020 flood damages would be along the Ohio River. which is particularly vulnerable to a flood greater than any of record, Much of the storage, in addition to reducing tributary flood damages, is also needed to control such extreme flood occurrences. Although rare floods have little effect on average annual dollar damage determinations, such a potential constitutes a major problem in the basin. Such an occurrence could overtax existing protection works and cause billions of dollars of damage, create major disruption in the regional economy and cause extensive human suffering and loss of life.

The plan to 2020 includes nearly half a million acre-feet of sediment storage in upstream detention structures and about two million acre-feet in major flood control reservoirs in the development program. Storage volumes for sediment, and evaporation, and seepage losses are included in the storage capacities specified for each water resource development purpose.

FORMULATION OF FRAMEWORK PLAN

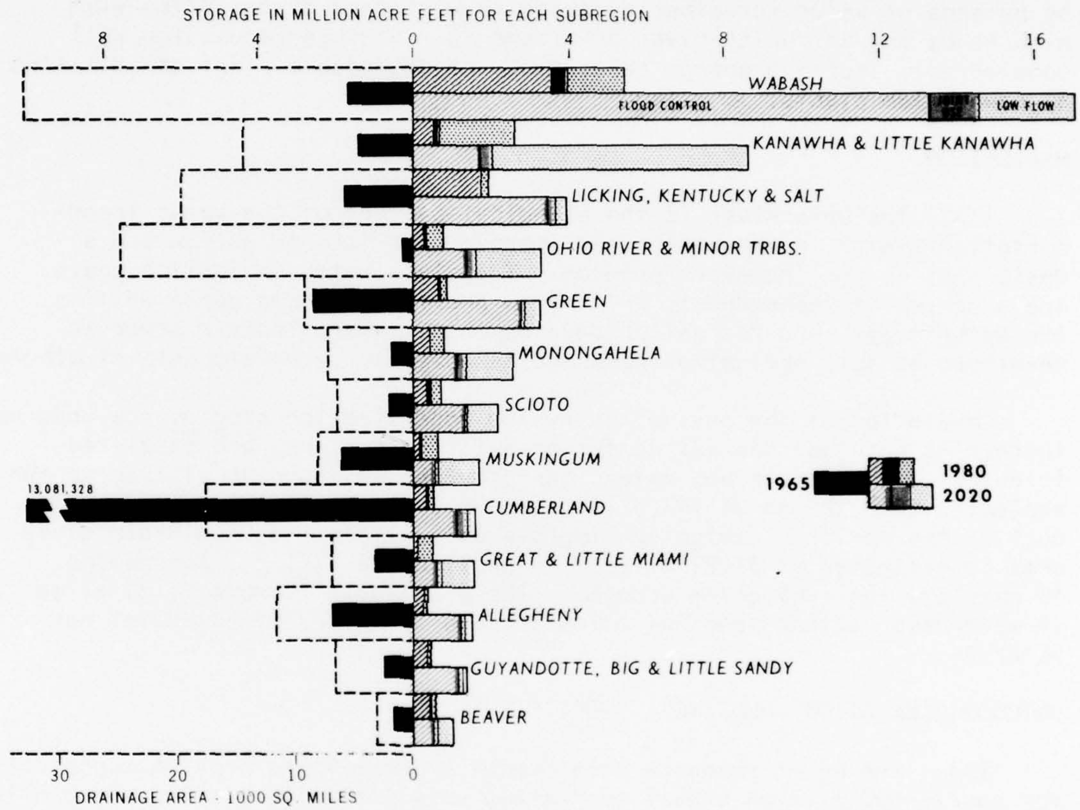
130. The framework development plan to year 2020 includes 19.3 million acre-feet of storage for increase of low streamflow to serve water supply withdrawal and stream quality needs. One million acre-feet of this is in the program for upsteam watershed projects. Over 3.2 million acre-feet of this required low flow supplementation storage can be obtained from joint use of seasonal flood control storage space within identified storage sites and there may be more opportunity for joint use in the additional reservoirs required. Low flow regulation needs for the Ohio River are served by providing about one million acre-feet of storage above Pittsburgh, Pa., which would increase the base flow during critical periods by about thirty percent.

Execution of the plan would result in adequate water quality for most water biota. The plan as presently defined is based on a complementary program of secondary treatment of all wastes prior to flow augmentation. Together the plan and that program would provide a minimum of 4 p.p.m. of disolved oxygen in the basins streams except in periods of severe drought. Higher quality of streamflow would require added treatment, further augmentation of stream flows or a combination thereof. Sufficient water for withdrawals and consumptive use to 2020 is provided from wells, stream flow or storage.

The framework program provides 15.8 million acre feet of new storage to be in place by 1980. Of this total 8.8 million acre feet is available in sites in which field investigations to some degree have been made. Joint use will reduce the remaining new storage required by 1980 to 7.0 million acre feet. Of this amount 60 percent is for water supply and water quality control where storage is needed close to the problem area. The remaining 40 percent is for control of tributary and Ohio River floods. A portion is placed in the early action portion of the program to allow for inclusion of this type of storage in those reservoirs which are selected for water supply and augmentation for water quality control. This process of combined storage developments makes best use of the sites available.

131. The following chart shows the distribution of storage in the plan and in the going program. The drainage areas of the subregions are given so that the magnitude of storage can be compared to area.

**STORAGE CAPACITY REQUIRED BY 2020
AND THAT IN THE 1965 GOING PROGRAM**



HYDROELECTRIC POWER

132. The Ohio Basin has adequate resources to meet electric power requirements. The preponderance of power generation will be at thermal electric steam plants. About 30 percent of the total generation by 2020 may be nuclear steam power. After 1980, it is assumed most new thermal power generating plants will use cooling towers or ponds to dispose of waste heat to prevent thermal pollution problems in streams. It is expected that hydroelectric plants, mostly pumped storage projects, will supply upwards to ten percent of total capacity requirements. Undeveloped hydroelectric potentials of about 7.2 million kilowatts are considered feasible of development by 1980 and are included in the program at an estimated cost of $0.8 billion. Of this, about 40 percent is pumped storage. All potential hydroelectric power sites have not been investigated; however, it appears that sufficient resources are available to provide a total of about 40 million kilowatts of hydroelectric capacity. All of this is by 2020. The investment from 1980 to 2020 is estimated to be over $3.7 billion.

Opportunity for hydroelectric power development will also be provided by release of water for other purposes from storage at dam sites with high heads and at run-of-river developments. Storage regulation will considerably increase energy generation and dependable plant capabilities at downstream plants.

NAVIGATION

133. The Ohio River is the principal element of the water transportation system in the basin, and improvements for navigation are a basic part of the framework program. The slack water navigation pools are a series of impoundments which also provide enhanced opportunities for water supply and recreation developments. Hydroelectric power is developed at some navigation dams and is potentially developable at others.

Completion of the navigation system modernization program now underway, increasing waterway channel depths on existing systems, and canalized tributary improvements and extensions provided in the plan will serve the projected 2020 demand of 147 billion ton-miles. The total construction cost of the required navigation improvements within the Ohio Basin study area is estimated at $1.81 billion in addition to $785 million needed to complete the 1965 going program. The plan would improve 2,187 miles of waterways, extend them 204 miles and add 323 miles of potential new waterway.

OUTDOOR RECREATION, HUNTING & SPORT FISHING

134. The water resource development program would provide opportunity for nearly 500 million annual recreation days including fishing and hunting. The cost of associated use facilities would be about $1.7 billion of which about $50 million would be sport fishing and hunting costs. Land costs to serve outdoor recreation are included in the overall cost of reservoir projects. Projection of recreation facilities at water resource and related land developments in the framework plan indicates a remaining deficit in the Ohio Basin of over 470 million annual recreation days including hunting and fishing which would have to be satisfied by recreation oriented programs with little or no significant impacts on water resources. Subbasin and basin-wide water and related programs covered in this report provide recreation development opportunities to serve public demand within reasonable driving distance, except in the vicinity of the major metropolitan areas of Pittsburgh, Columbus, Cincinnati, Louisville and Indianapolis. In these areas, single-purpose developments, or alternatives to water-based outdoor recreational opportunities may have to be adopted to fulfill the desires for recreation.

RELATED LANDS

The plan includes land treatment and management on 29.2 million acres in upstream watershed projects, above the potential reservoirs and in critical areas. Also included are the preparation of 1.3 million acres of land for irrigation and the installation of drainage on 4 million acres.

FRAMEWORK DEVELOPMENT PROGRAM SUMMARY

135. The framework development program, outlined in this appendix, provides for satisfying the water and related land needs as projected to 2020. The first capital investment cost of the program is estimated to total about $22 billion by 2020. Costs for other programs such as for additional land treatment and management on 21.9 million acres outside watershed project areas and providing for the remaining recreation needs are estimated to cost an additional $2.2 billion by 2020. The costs for water purification and waste water treatment, sewers, ground water development, correction of mine drainage, environmental programs were not defined because of lack of sufficient cost data available, but are an essential adjunct to the overall program.

The importance of preservation of scenic areas, historical and cultural sites and other environmental facotrs has been recognized and provision is made for detail planning consideration. These items will be significant factors in selecting projects and alternative sites within the framework plan. River reaches considered suitable for scenic river development in the national interest are currently being considered by Congress. In addition, state programs include wild and scenic river reaches for preservation. Implementation of these programs may require choosing some alternative sites for storage development more costly than those provided for in the program.

The following tabulation gives an accounting of the total storages required for the framework development program as summarized from the Ohio Basin subbasin analyses presented in attachment A.

OHIO RIVER BASIN
ACCOUNTING OF STORAGE CAPACITY FOR STREAMFLOW CONTROL
(IN ADDITION TO THAT PROVIDED IN THE GOING PROGRAM)

	Storage (Cumulative) 1980	2020
	(million acre-feet)	
A. WATER QUALITY CONTROL		
1. Storage required	4.47	9.40
2. Storage provided in identified potential sites	1.41	4.06
3. Additional storage required	3.06	5.34
B. WATER WITHDRAWALS		
1. Storage required	2.26	9.95
2. Storage provided in identified potential sites	1.05	2.05
3. Additional storage required	1.21	7.90
C. FLOOD CONTROL		
1. Subbasin and Ohio River control requirement	9.99	33.37
2. Storage provided in identified potential sites	6.34	18.77
a. for solving localized problems	(1.34)	(3.49)
b. effective in controlling both subbasin and Ohio River flows	(5.00)	(15.28)
3. Additional storage required(1)	3.65	14.60
D. TOTAL STORAGE VOLUME REQUIRED		
1. Water quality control, water withdrawals, and flood control ($A_1+B_1+C_1$)	16.72	52.72
2. Available in identified potential sites(2)	8.80	24.88
3. Joint use storage(3)	0.93	3.24
4. Storage required in addition to inventoried sites($D_1-D_2-D_3$)(4)	6.99	24.60
E. TOTAL NEW STORAGE CONSTRUCTION REQUIRED (D_1-D_3)	15.79	49.48

NOTES: (1) Remaining storage required for tributary protection and to reduce the Ohio River Standard Project flood to the maximum flood stage of record.

(2) See figure 1 of each subbasin and tables 24 and 25.

(3) Seasonal flood control storage space requirement differential available for low flow control joint use.

(4) Terrain indicates storage sites are potentially available.

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A summary of the total Ohio River Basin framework development program giving the amount and cost of individual programs is shown in the following tabulation.

FRAMEWORK PROGRAM FOR DEVELOPMENT OF WATER AND RELATED LAND RESOURCES

	Cumulative, in Addition to 1965 Program					
	To 1980		To 2000		To 2020	
STREAMFLOW CONTROL AND IN-STREAM USE	Amount	Cost (billion dollars)	Amount	Cost (billion dollars)	Amount	Cost (billion dollars)
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use............million acre-feet..	5.80	1.40	8.70	2.18	16.11	3.96
2. Control of Floodflows						
a. Reservoir and Detention Storage.......million acre-feet..	9.99	2.51	15.89	3.99	33.37	8.50
b. Local Protection Projects........................miles..	152	.15	320	.25	488	.34
c. Channel Improvement...............................do....	2,394	.09	3,037	.12	6,328	.24
d. Flood Plain Information Studies.......number of studies..	200	.005	450	.011	700	.018
3. Navigable Waterways						
a. Improvements in 1965-Program System....miles of channel..	2,187	.454	2,187	.646	2,187	.662
b. Potential Extensions and New Waterways............do....	172	.014	400	.944	527	1.444
4. Hydroelectric Power, Installed Capacity..........megawatts..	7,200	.81	20,100	2.21	40,000	4.50
Total (rounded)......................................		5.44		10.35		19.37
RELATED PROGRAMS						
1. Outdoor Recreation, Sport Fishing, and Hunting..............................million man-days..	132.7	0.46	199.1	0.70	494.6	1.72
2. Watershed Land Treatment(1) and Management...............................million acres..	11.4	.29	25.6	.63	29.2	.73
3. Lands to be Irrigated(2).....................million acres..	.1	.01	.7	.06	1.3	.12
4. Lands to be Drained(2).......................million acres..	3.2	.42	3.8	.51	4.0	.54
Total...		1.18		1.90		3.11
Grand Total..		6.62		12.25		22.48
Remaining demands - To be met by affiliated programs.						
1. Outdoor Recreation, Sport Fishing, and Hunting..............................*million man-days*..	179.5	0.64	449.5	1.58	471.4	1.64
2. Additional Land Treatment and Management.................................*million acres*..	7.0	.17	13.8	.35	21.9	.55
Total...		.81		1.93		2.19

(1) Includes land treatment and management in potential watershed projects, above potential storage reservoirs, and critical erosion areas.

(2) Preparation of lands and onfarm facilities.

FORMULATION OF FRAMEWORK PLAN

The relationship of capital investments that will be required within each subbasin to implement the Ohio Basin Comprehensive Framework Plan of Development at an estimated cost of $22 billion is as follows:

Subbasin	Captial Investment Required to Implement Development Program 1965-1980 Percent of Total	1965-2020 Percent of Total
Allegheny	3.1	3.8
Monongahela	7.0	5.1
Beaver	3.1	5.6
Muskingum	3.8	3.9
Kanawha, Little Kanawha	14.1	12.7
Guyandotte, Big Sandy, Little Sandy	2.2	3.5
Scioto	4.3	4.2
Great Miami, Little Miami	4.3	3.9
Licking, Kentucky, Salt	8.9	6.4
Green	3.8	5.1
Wabash	27.0	29.6
Cumberland	4.4	3.9
Ohio Main Stem & Minor Tributaries	14.0	12.3
TOTAL - OHIO BASIN	100	100

SCHEDULE OF DEVELOPMENT PROGRAM

Timely development of water and related land resources as outlined in the framework plan will provide the goods and services which can best satisfy the projected basin needs. Implementation of the plan as scheduled will support a sound economy and solve some social problems in the Ohio Basin by sustaining job opportunities, reducing flood losses, providing necessary water supplies, meeting electric power generation needs, increasing agricultural production, providing facilities for economic transport of bulk commodities and more opportunities for outdoor and leisure time activities. The degree of success of implementation and accomplishment of the plan to serve the projected population and economic growth will be primarily dependent on timely effective management by responsible agencies, especially in the provision of adequate financial support.

Pollution problems are critical and need immediate remedial measures. Storage reservoirs for flow supplementation upstream of critical problem areas should receive high priority. Replacement of outmoded locks on the Ohio River should be expedited to relieve the extremely congested conditions existing or projected for the immediate future. Implementation of non-structural measures relating to flood damage reduction, environmental consideration and improved land management are also urgent. In general, problems of overall basin flood control, erosion prevention, navigation in tributaries, water supply, etc., for an expanding economy fit more logically into long-range budgeted programs where an equitable share must be accomplished each year. There are many local problems in all categories that are urgently needed.

The costs presented are based on the units of development needed to be in place by the time periods designated. Care must be used in applying these figures to project scheduling as it often becomes necessary to construct a project to its ultimate capacity at one time. Therefore, additional studies are needed to obtain detailed scheduling and budgeting data.

Water resource project and program formulation for the Appalachian Development Program, and in the Kanawha, and Wabash Basins and other more detailed comprehensive programs are a part of satisfying the total basin needs. Projects recommended in these studies fit into the Ohio River Basin framework plan. Nevertheless, as detailed investigations are made, there will be some modification required in all the plans. Therefore, periodically the framework plans should be updated. It should be pointed out that the inclusion of potential projects of any type in the framework plan for the Ohio River Basin does not constitute an indorsement of that project by the affected states and participating federal agencies.

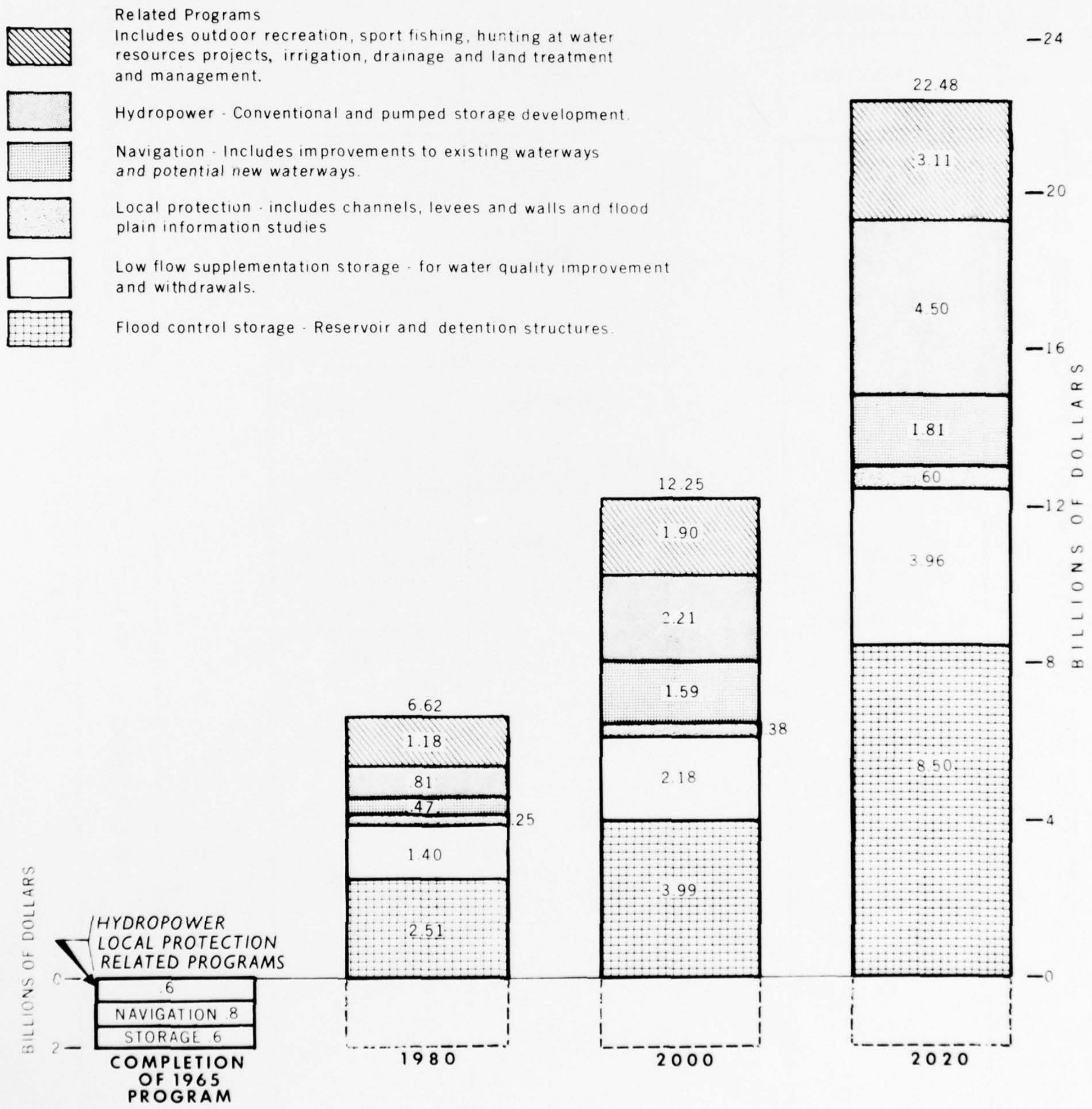
The costs of the various functional aspects of the comprehensive Ohio River Basin framework program for water and related land resource

development by time periods are summarized in the chart on page VI-23. The categories of investment in terms of detailed investigations, structural and nonstructural classes and an indication of Federal-non-Federal costs are shown in the chart on page VI-24.

OHIO BASIN FRAMEWORK DEVELOPMENT PROGRAM

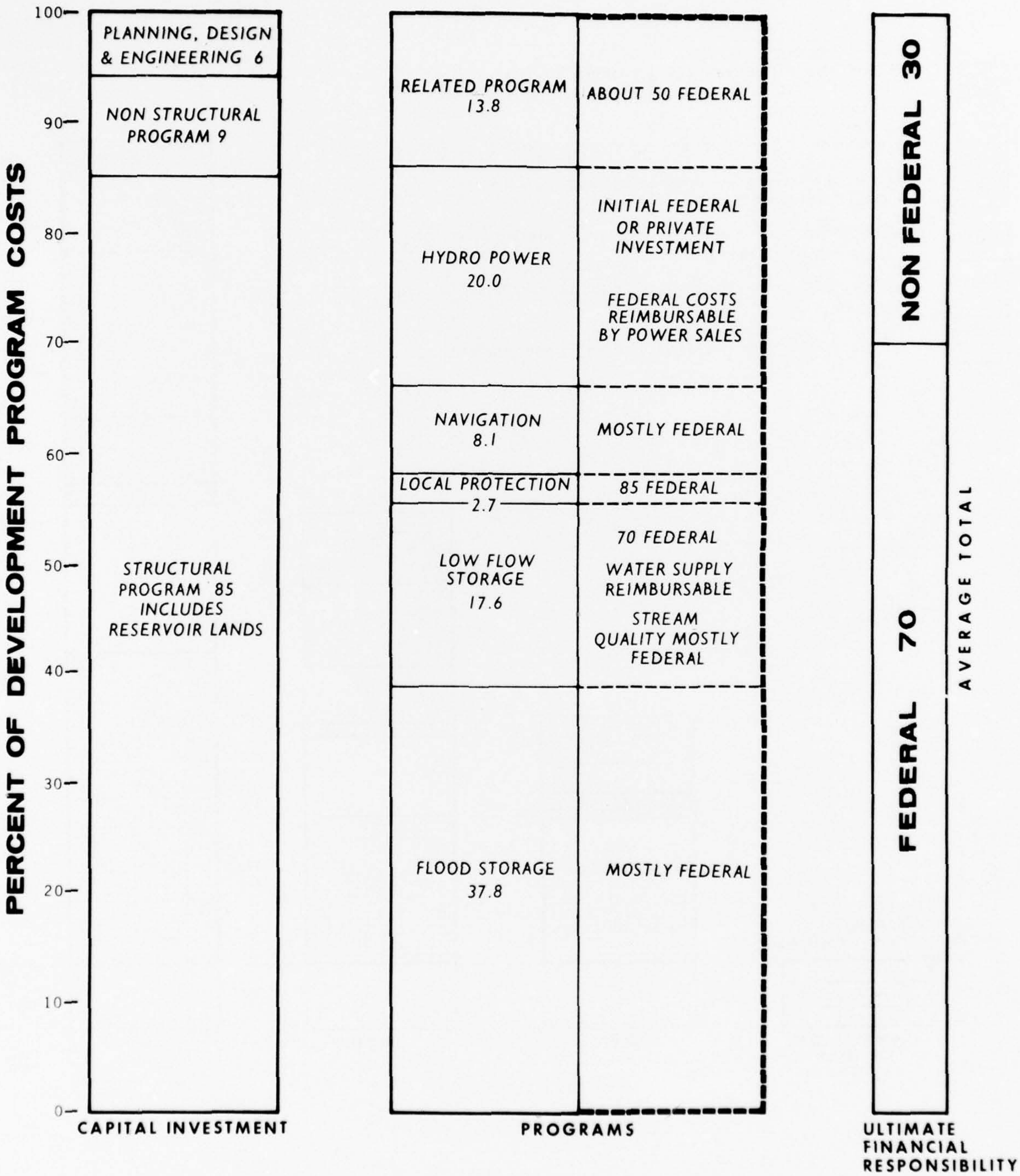
FIRST COSTS IN BILLIONS OF DOLLARS

(CUMULATIVE)



OHIO RIVER BASIN FRAMEWORK DEVELOPMENT PROGRAM

CATEGORIES OF INVESTMENT
FIRST COSTS TO 2020



BASED ON RECENT PROGRAM AVERAGES

IMPLEMENTATION

The development program for the Ohio River Basin can be implemented under existing Federal, state and local laws and programs with minor modifications and proper coordination of program planning and resource management. Continuation and acceleration of going programs for water resources and related land development are essential to meet the demand for goods and services. Additional funds for project construction and resources management are urgently needed. Difficulty in arranging for financing by the non-Federal participators in these programs may require modifications in cost sharing procedures and legislative actions for efficient and effective short- and long-term financing. Special legislative actions of the nature presently routine at all levels of government should serve most needs. Establishment of uniform equable cost allocations to the needs served and cost sharing of the benefit recipients should be firmly established.

Efficient implementation of the comprehensive framework plan must include:

a. An organization for continued coordination of the numerous studies of various agencies and interests required to implement the plan. Its duties should include the preparation of coordinated budgets for planning needed to implement the plan and provide for continuous updating.

b. Coordination of operations to maximize the potential of all related development resources.

c. The extension of programs to collect basic data on water resources and use, especially as related to water supply and quality as related to efficient development and use.

d. Programs to efficiently manage water resources and related land use especially that required for storage development, lands in flood plains and those of scenic, ecological and other environmental importance.

e. Progressive policy determinations in regard to uniformity of cost allocation procedures and economic justification criteria by all interests as applied to all projects and alternatives to assure best development and use of resources.

In implementing the plan of development for the Ohio River Basin careful evaluation of the alternatives will be required. The study has presented the apparent most logical means of providing for the needs for water resource and related land developments. However, appraisal of alternatives as applied to specific problems and locations will be a necessary part of project and program planning. Coordination with all pertinent interests during preliminary planning, design, construction

and management of the facilities is a necessary part of the implementation program.

Responsibility for implementation of various aspects of the program must be defined and full coordination exercised. The responsibility of the Federal agencies participating in the study is defined by law and policy. It must be recognized that these can change and undoubtedly will but based on present authority and policy, the agencies' responsibilities are generally as follows.

116. The Department of Agriculture is responsible for administering the program of assisting in providing flood control in upstream agricultural flood plains and upstream urban areas where flood damages of minor magnitude exist and for developing multiple-purpose storage in the flood water detention structures as pertinent. The Watershed Protection and Flood Prevention Act, Public Law 566, 83rd Congress, as amended, provides for assisting states and local agencies in solving water and related land problems. The planning is limited to watersheds or sub-watersheds of not more than 250,000 acres in area and maximum flood detention capacity of 12,500 acre-feet and a total storage for all purposes of 25,000 acre-feet in any one structure. Agreements must be obtained from owners of at least 50 percent of the land in watersheds above each retention reservoir to carry out recommended soil conservation measures. Upstream watershed projects shown in the plan are those which could meet these requirements.

In addition to watershed programs under Public Law 566, the Department of Agriculture administers supervision of National Forests and collects agricultural data and makes studies for economic research.

The agreement of September 23, 1965, between the Soil Conservation Service of the Department of Agriculture and the Corps of Engineers defines primary areas of responsibility with respect to flood protection by engineering works. Full coordination and review of each agency's plans by the other are provided to avoid conflict and duplication.

117. The Corps of Engineers in cooperation with all other interests has major responsibility for widespread comprehensive water resources development including reservoir impoundment of flood and excess flows for later release, local flood protection projects, flood plain information studies, flood plain management programs, hydroelectric power generation, navigation, irrigation, drainage, recreation, and conservation of fish and wildlife and aesthetics at project sites.

The Department of Commerce's Environmental Science Services Administration provides weather forecasts, flood warning service and low flow forecasts.

FORMULATION OF FRAMEWORK PLAN

The Public Health Service, Department of Health, Education, and Welfare, is responsible for the health aspects of water resources. It is currently preparing a series of "Health Guidelines for Water Resource and Related Land Use Management." Use of these Guidelines in water resource planning should result in measures to eliminate or minimize existing and potential health threats thereby benefiting the health and well-being of man.

The Department of Interior has a responsibility for topographic and geologic mapping, collecting basic data on water resources, and managing fish and wildlife, minerals and mining and recreation. These programs are often cooperative with state governments. The Department administrates National Park areas, energy sales from public power facilities and water pollution control programs affecting interstate streams. Technical assistance and guidance to state agencies and others for self-supported, outdoor recreation are a part of their program.

The Federal Power Commission issues preliminary permits for studies of potential hydroelectric projects, and the issuance of licenses, limited to 50 years, for the construction and operation on non-Federal hydroelectric projects. The Commission may condition licenses for protection of life, health, and property; flood control; navigation; recreation; scenic beauty and fish and wildlife.

The states, local governments and private sectors of the economy investigate many resource development projects, carry out the implementation of plans of development on their own and in cooperation with Federal development. On many Federal projects they provide for a share of lands, easements, rights of way and maintain the works. Flood plain management is primarily the responsibility of State and local governments.

Water supply is generally a state, local or private responsibility and if provided by a Federal water resource development project, the cost is reimbursed by the users. Ground water development, pumping plants for water supply withdrawals, treatment and distribution systems are generally local responsibilities. Water quality storage in Federal storage projects is generally a non-reimbursable Federal expense if benefits are widespread.

The maintaining of adequate measures for prevention and control of water pollution is primarily a state responsibility.

The preservation and enhancement of the environmental factors of unusual significance is a responsibility of all. Each Federal, State and local agency, industry and private citizen can assist in keeping America beautiful. It is the responsibility of all water resources and related land planning and construction interests to give consideration to historic and archeological sites, areas of rare ecology and to preserve and enhance green spaces, and areas of scenic beauty when practical.

APPENDIX K

ATTACHMENT A

SUBBASIN ASSESSMENT
OF
OHIO RIVER BASIN FRAMEWORK PLAN FORMULATION

Allegheny

Monongahela

Beaver

Muskingum

Kanawha and Little Kanawha

Guyandotte, Big Sandy and Little Sandy

Scioto

Great Miami and Little Miami

Licking, Kentucky and Salt

Green

Wabash

Cumberland

Ohio River and Minor Tributaries

APPENDIX K

ATTACHMENT A

SUBBASIN COMPONENTS OF OHIO RIVER BASIN FRAMEWORK PLAN FORMULATION

TABLE OF CONTENTS

APPENDIX K

ATTACHMENT A

SUBBASIN COMPONENTS OF OHIO RIVER BASIN
FRAMEWORK PLAN FORMULATION

TYPICAL TABLE OF CONTENTS FOR EACH SUBBASIN

Figures

Tables

ATTACHMENT A

Introduction to Subbasin Assessments

The primary objective of the subbasin analyses is to assess the geographic components of the Ohio River Basin framework plan. Both requirements and resources were assessed largely on standardized data to facilitate comparability among subbasins. Consequently, numbers presented should not be construed as being absolute evaluations and used out of context for other purposes. The results will, however, serve as a guide to future, more detailed assessments of needs, problems and solutions. The subbasin assessments provide the basic comments, or "building blocks," for formulation of the Ohio River Basin Framework Plan of Development.

The determination of resource availability, development needs, and possible problem solutions starts in the headwater areas. Each element must be considered, in turn, from the source to the Ohio River and, hence, to the mouth where it joins the Mississippi River. Basin development needs and resource availability have been summarized in Section IV and V of this appendix. Details relating to basic water and land resources elements may be found in such appendices as C, Hydrology; E, Ground Water Distribution & Potential; and F, Agriculture. Needs of the basin's growing economy which serve as a base for determining demands of the resources may be found in the Projective Economic Study, Appendix B; and other pertinent appendices such as D, Water Supply & Water Quality; M, Flood Control; and L, Navigation; G, Fish and Wildlife Resources; H, Outdoor Recreation; I, Electric Power; and J, State Laws, Policies and Programs. Those appendices deal with the assessment of individual water uses, solutions to problems and means for meeting present and future requirement. Evaluations developed in the appendices and carried forward to this Appendix K provide the basic information and data for subbasin framework planning.

For each subbasin, the appendices were studied, data transformed to obtain comparable relationships, combined on a subbasin or subarea basis and analyzed in various ways to obtain common units useful for plan formulation studies. The major problem areas in each subbasin were located on a map and the time period in which they become critical designated. Existing water resource developments and identified potential sites were also shown. Schematic diagrams were prepared for each subbasin together with pertinent data for each time period to reflect the relationship of stream systems and the sequential distribution of needs for control of streamflows.

After solutions for flood control, water supply requirements and water quality problems were defined in each subbasin, the potential upstream watershed projects and major multiple-purpose storage reservoir components were evaluated for their potentiality in satisfying recreation,

fishing and hunting, or other needs. Subbasin demands that could not be met (and in some cases surplus resources which could be made available) were referred for basin-wide analysis.

Reaches of the Ohio River and its minor tributaries were analyzed similarly to the individual subbasins. In many cases, the solution of subbasin problems provided the required control of streamflows desired on the Ohio River.

The overall Ohio River Basin framework plan was then formulated by integrating the results of subbasin and Ohio River subarea assessments and supplemental measures into a composite to provide for basin water and related land resource development needs. The initial investment costs were estimated based on cost relationships developed in the various appendices and other available agency data.

The methodology procedures are briefly summarized as follows:

1. The basic input data for the analysis was summarized from the various appendices. These data include a base year amount of supply, use, demand of, or capability of providing for goods and services, and projected increase in demand on water and related land resources and for most items established the water resource development and related land requirements.

2. The available resources and potential developments as defined in the appendices and summarized in Appendix K tables were evaluated as to their capabilities in meeting the projected increase in demand. A determination was then made as to the portion of the total increase in demand that logically should be met by water and related land resource developments.

3. Reservoir capacity requirements were established by considering ground water and streamflow for water supplies; flow supplementation needs for stream quality; and local flood protection and management techniques.

4. Multiple-purpose storage use for flood control, water supply, low flow augmentation for stream quality control, and the provision of storage and reservoir pools to serve other needs were then established.

5. Flood control measures required in addition to storage, navigation facilities and hydroelectric power developments as developed in other appendices were then accounted for.

6. An evaluation was made of outdoor recreation opportunities and land treatment and management programs directly related to the water resource developments established for streamflow control and in-place use.

7. Remaining storage requirements in addition to that which could be provided at inventoried sites were accounted for to the extent that resources indicated such development would be the most practical means of serving the unsatisfied demands for water supply and streamflow control.

Each subbasin text discusses the planning environment; demand for water and related functions services, capability of going programs, resource availability, and an assessment of resource development requirements. The map, analysis schematic and the four tables following the text for each subbasin are explained in the following paragraphs.

Table I for each subbasin presents a reference base year amount and the projected increases in the demand to 1980 and 2020 for the goods and services listed in the first column. These demands are given in the units used in the basic inventory in the other appendices. The base year amount is that portion estimated to have been utilized in the base year or in the case of navigation and flood damage prevention it is the capability of the completed 1965 going program. The base year varied depending on the information available to the agency collecting and analyzing the basic data and are given in the next tabulation.

BASE YEAR REFERENCES FOR
ELEMENTS OF DEMAND FOR WATER AND RELATED FUNCTIONS AND SERVICES

Water Withdrawal (Average Daily)			
Municipal and Industrial		1960	
Electric Power Cooling		1965	
Rural Communities		1960	
Rural Domestic and Livestock		1960	
Irrigation		1960	
Stream Assimilation of Organic Waste Effluent	(Average Daily)	1960	Organic wastes
Flood Damage Prevention	(Average Annual)		Includes damages prevented by projects existing, under construction or in preconstruction planning in July 1965, by upstream watershed projects authorized as of July 1965
Waterway Freight Movement	(Annual)		Capability of projects existing, under construction or in preconstruction planning as of December 1965.
Hydroelectric Power - Installed Capacity		1963	Capacity existing or under construction
Outdoor Recreation	(Annual)	1960	
Sport Fishing	(Annual)	1960	
Hunting	(Annual)	1960	
Commercial Fishing	(Annual)	1960	
Land Treatment and Management	(Land Area)	1965	Land in authorized watershed projects
Drainage	(Land Area)	1960	
Irrigation	(Land Area)	1960	

INTRODUCTION TO SUBBASIN ASSESSMENTS

In some subbasins there are resources available greater than the base year need. The base year amount plus projected increases equals the gross demand with the exception of outdoor recreation, hunting and especially fishing. (See Tables 11, 12 and 13, Appendix K).

The map presented for each subbasin shows the principal water supply, water quality and major urban flood problems which can be solved by stream flow control and must be analyzed on a subbasin system basis since the solution may have an effect on other parts of the basin's water resources development problems and needs. Small water supply need areas, water quality problems, erosion, environmental considerations and so forth are not shown although they are included in subbasin-wide analysis. All the Federal and the significant sized non-Federal reservoirs and the upstream watershed project areas authorized under Public Law 566 as of 1965 in the going program are shown. Potential reservoirs are named and upstream watershed projects are numbered. Details on going program projects can be obtained from tables 15 to 21 and for potential projects on tables 24 and 28.

The analysis schematic shows the problem areas which can generally be served by developing storage upstream of their locations. Reservoirs and upstream watershed projects in the going program are also shown.

The following tabulation defines various aspects of the going programs and the base year used in the subbasin analysis.

GOING PROGRAMS - SUBBASIN ANALYSIS

Reference Dates and Status of Conditions

A. STREAMFLOW CONTROL AND IN-STREAM USE	
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	
Federal Reservoirs	1965 E,UC,AP(1)(2)
Non-Federal Reservoirs	1965 Existing
Upstream Watershed Projects	1965 Authorized(3)
2. Control of Flood Flows	
a. Storage	
Federal Reservoirs	1965 E,UC,AP
Non-Federal Reservoirs	1965 Existing
Upstream Watershed Projects	1965 Authorized
b. Local Protection	
Federal	1965 E,UC,AP
Non-Federal	1965 Existing
Upstream Watershed Projects	1965 Authorized
3. Navigable Waterways	
Federal	1965 E,UC,AP
Non-Federal	1965 Existing
4. Hydroelectric Power	
Federal and Non-Federal	1963 Existing and Under Construction
B. RELATED PROGRAMS	
1. Outdoor Recreation - Recreational Activity at Federal and State Areas, exclusive of Monuments and Memorials, and Major Local Areas Having over 50 Acres of Water.	1960 Inventory
2. Sport Fishing	1960 Inventory
3. Hunting	1960 Inventory
4. Land Treatment and Management - (Upstream Watershed Projects)	1965 Authorized
5. Irrigation (Land with Economic Potential)	1960 Inventory
6. Drainage (Land with Economic Potential)	1960 Inventory

(1) 1965 reference in all cases indicates status as of July 1965, except navigable waterways which is December.

(2) E - Existing
UC - Under Construction
AP - Advanced Planning for construction

(3) Upstream watershed projects authorized for development.

Table 2 for each subbasin lists those items most significant in determining the storage capacity requirements. Item A develops tne supplemented streamflow required in addition to that provided by the going program.

Item B gives background data used to determine the storage for water supply requirements and to make up consumptive uses where these become a significant factor in maintaining sufficient streamflow to satisfy the needs. Total withdrawal amounts must be adjusted to determine the portion to be furnished from storage by subtracting supplies furnished from ground water and available stream flows. The mechanics of this operation depend on the location of storage, need areas, return flows and joint use, therefore requiring a systems operation analysis. Schematic Figure 2 was used as an aid in the procedures for that purpose.

Item C presents a summary of magnitude of the remaining flood damages. Flood damages in upstream areas are generally rural and widespread. Damages in major urban areas are concentrated along a relatively short reach of the streams. Other flood plain damage areas include transportation routes, and widely dispersed industrial, residential, agricultural and other developed areas.

Table 3 for each subbasin gives the accounting of the storage capacity for streamflow control as required and determined to be a part of the framework plan.

Item A gives the storage required in addition to that in the going program to provide the desired dissolved oxygen in the stream. Storage provided in identified potential sites is that amount considered feasible of development in reservoir sites which have been studied in some detail by the Corps of Engineers or state agencies and in the potential upstream watershed program defined by the Department of Agriculture in Appendix F. Tables 24 and 25 of Appendix K presents the information for potential reservoir sites and potentially feasible watershed projects. It is to be noted that the amount of total capacity of storage at a site can not always be feasibly developed and the plan may include less than the total. The additional storage required is the remaining amount needed to satisfy the plan. It is considered available based on a general knowledge of the topography and runoff characteristics of the area but more studies are required to determine specific potential reservoir sites.

Item B gives the storage required to satisfy the withdrawal needs after available ground water and supplemented streamflow for water quality control has been considered as a source. The identified amount can be obtained by subtracting from Item D.2 the items A.2 and C.2.

Item C gives the storage required for flood control in the subbasin and also the additional amount that appears to be the most appropriate

share for controlling large floods on the Ohio River. There may be alternatives in other subbasins that could serve these needs. The storage provided in the identified potential sites for flood control has a similar definition as that previously given in the discussion on item A. Storage sites which would probably be constructed with ungated flood detention storage are not considered effective in controlling Ohio River floods and are included in item C.2a for solving localized problems.

The additional storage required is the amount needed but for which detailed studies are required to define the sites for the storage structures. Detailed studies will also result in exchanges of storage requirements allocated to the various purposes between identified sites.

Item D gives the total storage capacity required to fulfill the needs of the framework plan, the amount which is in the identified available potential sites that were inventoried, the amount in joint use storage of those sites to satisfy both flood control and low flow needs and the remaining amount required by finding additional new reservoir storage sites. The total amount of new storage required by the plan is item D.1 minus the joint use storage.

Because of the generalized nature of determining large area net demands for water supply and water quality, and the analysis procedures used, the shares of low flow storage requirements indicated may vary from that allocated to the purposes in detailed planning. Since the storages given in the plan may serve multiple uses, the reduction in storage for one function may create an additional need for water to provide for the others. The amounts of additional storage required at unidentified sites does not consider joint use possibilities.

Table 4 for each subbasin is the summary assessment of total resource development requirements. Park 1 is the amount which has been clearly defined as a part of the framework plan of development in that subbasin. Part 2 is the remaining requirements for which there may be exchanges from one basin to another as the plan is implemented. It also includes (a) storage likely to be developed for streamflow control at unidentified sites, (b) remaining requirements could be served at least in part by (a) above, and (c) those portions not specifically defined as being water resources projects and related land development items.

Hydroelectric power sites identified in the subbasin are assumed to be utilized in the plan by 1980. The remaining demand for hydroelectric power to 2020 was assessed on an Ohio Basin-wide basis.

INTRODUCTION TO SUBBASIN ASSESSMENTS

Commercial fishing was also assessed on a basin-wide basis since locations of development had not been defined. There are no specific water resource development needs for commercial fishing in addition to water quality provisions of the program and improved management. Research is needed on habitat, cultivation of species and techniques of harvesting, processing and marketing. A portion of the remaining outdoor recreation assessed in Part II can undoubtedly be provided at water resources projects but a large part of this may require single purpose water resource development or alternative means. Sport fishing and hunting has not been specifically defined as to where it will be satisfied but a portion of this can be provided at water resource projects and on the related lands.

The land treatment and management outside watershed projects, preparing land for irrigation and installation of drain tile has not been defined as to where this might be implemented. The amounts in the assessment are taken from Appendix F, Agriculture. Detailed studies are required to define what parts of these are water resources project related lands. Costs for conservation pool storage, sediment control and contiguous project lands for outdoor recreation and fish and wildlife are included in Part I of the water resource development program. Part I includes all aspects of the potential upstream watershed projects.

Summary of Subbasin Assessment

The Ohio River Basin Comprehensive Framework Development Program formulated for the entire basin in Appendix K , is based on a summation of the subbasin analysis and accounting presented in Attachment A.

The following summary tables are similar to the individual subbasin tables 1,3 and 4. Table 2 for the subbasins is composed of details for subbasin analysis and not of the nature susceptible to summarizing.

Summary Table 1 gives the Ohio Basin base year summation of goods and services and the projected increases remaining to be satisfied by 1980 and 2020. Flood damage prevention, waterway freight movement and land treatment and management are based on 1965 programs. In other instances where some other base year program capability or use served as a base for subbasin analysis, the summation of the increased demand over the going program differs from the net needs beyond the 1965 program capabilities presented in the main body of Appendix K. The most notable items are in the net needs both in the data in other appendices and the tables herein as compared to data in Sections IV, V and VI of this Appendix and in the Main Report.

Summary Table 2 is the accounting for the storage needs of the Ohio Basin. The format is the same as on the subbasin table 3. Since 1965 going program resource capabilities were used as a base, this table agrees with the program summary table in the main body of Appendix K.

Table 3 is a summation of the additional requirements above that provided by the going program and have been compiled from the data in table 4 of the subbasins. For storage, navigable waterways, hydropower, outdoor recreation and watershed project land treatment and management the figures are based on the 1965 going program. Part 2 remaining requirements presents inventory data from other appendices using various base year references in lieu of 1965 going program capabilities and consequently differs in the same manner as summary table 1 from the material presented in the main body of Appendix K and the Main Report.

TABLE I

SUMMATION OF SUBBASIN COMPONENTS
OHIO RIVER BASIN
DEMAND FOR WATER AND RELATED FUNCTIONS AND SERVICES

	Unit	Base Year Amount	Projected Increase[1] 1980	2020
Water Withdrawal				
Municipal and Industrial	Million Gallons Per Day	10,728.0	3,306.3	17,528.9
Electric Power Cooling	Million Gallons Per Day	19,200	9,800	43,800
Minerals and Mining	Million Gallons Per Day	290	221	1,604
Rural Communities	Million Gallons Per Day	558.0	115.2	376.4
Rural Domestic and Livestock	Million Gallons Per Day	159.15	9.17	134.64
Irrigation[2]	Million Gallons Per Day	27.2	74.4	654.6
Stream Assimilation of Organic Waste Effluent[3]	1,000 Population Equivalents	4,141.4	1,887.3	9,264.4
Flood Damage Prevention[4]	Million Dollars Annually	239.37	144.32	295.65
Waterway Freight Movement[5]	Million Ton-Miles Annually	42,620	9,820	105,570
Hydroelectric Power - Installed Capacity	Megawatts	1,503.1	7,200	40,000
Outdoor Recreation	Million Recreation Days	58.3	332.3	971.3
Sport Fishing	Million Angler Days	21.76	3.12[6]	14.85[6]
Hunting	Million Hunter Days	21.66	3.41[6]	6.49[6]
Commercial Fishing	Million Pounds	2.5	11.7	25.0
Land Treatment and Management	1,000 Acres	3,443	18,370	51,032
Drainage	1,000 Acres	11,035	4,313	5,582
Irrigation (Land Area)	1,000 Acres	50.0	165.0	1,369.3

NOTES: (1) Base year amounts plus projected increase equals gross demands.

(2) Withdrawal shown is for average year; drought year may be 45 percent higher.

(3) Residual biochemical oxygen demand after 85 percent waste removal by treatment.

(4) The dollar amounts (1980 and 2020) are indices to the magnitude of the problem and the protection measures required to reduce the potential damaging effects of floods.

(5) An index to the canalization and waterway facilities required to accommodate the transport of waterborne freight.

(6) Net requirements.

TABLE 2

SUMMATION OF SUBBASIN COMPONENTS
OHIO RIVER BASIN
ACCOUNTING OF STORAGE CAPACITY FOR STREAMFLOW CONTROL
(IN ADDITION TO THAT PROVIDED IN THE GOING PROGRAM)

	Time Period 1980	2020
	Storage (1,000 Ac Ft)	
A. WATER QUALITY CONTROL		
1. Storage required(1)	4,471.2	9,396.5
2. Storage provided in identified potential sites	1,410.4	4,063.4
3. Additional storage required	3,060.8	5,333.1
B. WATER WITHDRAWALS		
1. Storage required	2,264.4	9,957.1
C. FLOOD CONTROL		
1. Subbasin and Ohio River control requirement	9,988.9	33,368.4
2. Storage provided in identified potential sites	6,338.6	18,768.4
a. for solving localized problems	(1,342.1)	(3,491.7)
b. effective in controlling both subbasin and Ohio River flows	(4,996.5)	(15,276.7)
3. Additional storage required(2)	3,650.3	14,600.0
D. TOTAL STORAGE REQUIREMENT		
1. Water quality control, water withdrawals, and flood control	16,724.5	52,722.0
2. Available in identified potential sites(3)	8,798.7	24,885.6
3. Joint use storage	935.1	3,244.0
4. Additional storage required(4)	6,990.7	24,592.4

NOTES: (1) Storage capacity to provide supplemental flows when required.

(2) Remaining storage required to reduce the Ohio River Standard Project flood to the maximum flood stage of record.

(3) See figure 1 of each subbasin.

(4) Terrain indicates storage sites are potentially available.

TABLE 3

SUMMATION OF SUBBASIN COMPONENTS
OHIO RIVER BASIN
SUMMARY ASSESSMENT OF RESOURCE DEVELOPMENT REQUIREMENTS

Program Elements	Unit	Provided in Going Program	Additional Requirement[1] 1980 Amount	1980 Capital Cost ($1,000)	2020 (Accumulative) Amount	2020 (Accumulative) Capital Cost ($1,000)
PART 1. TO BE FURNISHED BY IDENTIFIED RESOURCE POTENTIAL WITHIN SUBBASIN.						
A. Streamflow Control and In-Stream Use						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	7,113.6	2,460.1	546,400	6,117.2	1,412,300
2. Control of Flood Flows						
a. reservoir and detention storage	1,000 Ac Ft	17,268.5	6,338.6	1,579,300	18,768.4	4,775,400
b. local protection projects	Miles	578.7	152.0	150,400	488.2	341,900
c. channel improvement	Miles	961	2,394	92,600	6,233	242,600
3. Navigable Waterway						
a. improvement to existing waterway	Miles of Channel	2,217	1,203	454,000	1,445	539,000
b. new waterway	Miles of Channel	-	170	14,000	493	1,144,000
c. channel deepening to 12 feet	Miles of Channel	-	-	-	1,558	123,000
4. Hydroelectric Power - Installed Capacity	Megawatts	1,503.1	7,200	810,200	(Assessed on a Basin-wide Basis)	
B. Related Programs						
1. Outdoor Recreation[2][3]	Million Recreation Days	58.3	97.7	342,200	302.8	1,050,000
2. Watershed Project Land Treatment and Management[4]	1,000 Acres	3,443	8,266.7	208,200	21,167.1	530,800
COSTS - PART 1				4,197,300		10,159,000
PART 2. REMAINING REQUIREMENTS.						
A. Streamflow Control and In-Stream Use[5]						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	-	3,340.4	851,700	9,992.4	2,548,000
2. Storage for Control of Flood Flows	1,000 Ac Ft	-	3,650.3	930,800	14,600.0	3,723,100
3. Hydroelectric Power			(Assessed on a Basin-wide Basis)			
B. Related Programs						
1. Outdoor Recreation[2][6]	Million Recreation Days	-	241.0	833,500	669.0	2,321,400
2. Fish and Wildlife						
a. sport fishing[2][6]	Million Angler Days	21.76	3.50	12,300	15.07	53,000
b. hunting[2][6]	Million Hunter Days	21.66	3.49	12,200	6.50	23,000
c. commercial fishery			(Assessed on a Basin-wide Basis)			
C. Land Treatment and Management						
1. Lands Outside Watershed Projects	1,000 Acres	-	10,102.6	252,600	29,864.1	746,600
2. Irrigation (Acres to be Irrigated)	1,000 Acres	50.0	165.0	15,300	1,369.8	127,200
3. Drainage	1,000 Acres	11,035	4,212.9	567,200	5,085.2	686,600
COSTS - PART 2				3,475,600		10,228,900
TOTAL COSTS - (PARTS 1 AND 2)				7,672,900		20,387,900

NOTES: (1) Requirement in addition to that provided by going development programs.

(2) Costs shown are for facilities and such measures as may be required to implement the program; direct water and related land cost are (Part 1) or would be (Part 2) covered in the costs of developments supporting the activity.

(3) The number of outdoor recreation days shown include some sport fishing and hunting which could not be separately accounted for in available data.

(4) Land area and costs shown are for total land treatment and management requirements in watershed projects and cover both water related and other lands.

(5) Specific sites to provide storage capacity for streamflow control are not identified; however, terrain indicates favorable sites are potentially available.

(6) Because of population and resource distributions, remaining subbasin requirements for outdoor recreation, sport fishing and hunting not satisfied by water resource developments may require a trade off with adjacent subbasins or satisfied by other means.

ALLEGHENY

1. Planning Environment. - The Allegheny River drainage, together with that of the Monongahela River, comprises the headwaters of the Ohio River. The Allegheny subbasin occupies approximately 11,700 square miles, or 7 percent, of the Ohio Basin study area and contributes 60 percent of the Ohio River flow at Pittsburgh. It extends farthest north and east of the Ohio River tributary basins and, except for a small portion in southwestern New York, lies entirely within the western portion of Pennsylvania. Much of the upland area is rugged, heavily forested, and access roads are limited.

The subbasin's growing season is the shortest and snowfalls are the heaviest in the Ohio Basin. Although the average precipitation is less than that for the Ohio Basin, runoff from the Allegheny drainage is the highest of all the subbasins and contributes considerably to flood problems at Pittsburgh and along the Ohio River. In contrast, low-yield years and seasonal deficiencies in runoff result in droughts, shortage of water supplies, and other problems created by the lack of water.

Early pioneers migrating into the basin from the east found the area abounding with wildlife and other assets of nature. This prompted many to settle in the uplands, and a number of the small communities that were formed are still in existence. The majority of the population, however, is located in and near the metropolitan areas of Johnstown and Pittsburgh and other major population and industrial concentrations that have developed in the region.

The Allegheny subbasin, excluding the metropolitan area of Pittsburgh, has 6 percent of the population in the Ohio Basin study area, 5 percent of the employment, and accounts for over 11 percent of the industrial output. Mining was for many years an activity of major employment; but because of mechanization, that industry now employs only 10 percent of the labor force. Due to a shift in national markets, the Allegheny subbasin primary metals industry's share of employment also is expected to decline. Most employment is in manufacturing, trades, and services, and the work force here is expected to more than double by 2020. Today, steel mills, metal fabricating plants, and manufacturers of machinery and motor vehicles employ the largest share of industrial labor. The trend toward industrialization is continuing rapidly, and by 1980, over half the people in the subbasin are expected to live in industrialized urban areas.

2. Demand for Water and Related Functions and Services. - More intense use, additional development, and more efficient management of water and related land resources, along with diligent prosecution of other programs allied to water and land use, will be required to keep pace with projected demands for water and related functions and services in the Allegheny subbasin. Base year and projected increases that comprise gross demands for water and related functions and services are listed in table AL-1. Table AL-2 provides principal considerations in determining storage capacity requirements for control of streamflow.

There are critical flood problems within the basin. Continuing development in the flood plains, combined with excess flows from the Monongahela and Allegheny Rivers, creates a particularly serious flood problem at Pittsburgh - where damages average a million dollars per year - and contributes to problems farther down on the Ohio River. The concentration of industrial, commercial, and transportation activities at Pittsburgh creates large demands for water of satisfactory quality. Although a considerable portion of the Pittsburgh area water resource demands and problem solutions are in the Allegheny subbasin, the Pittsburgh area is included in the report in the upper Ohio River.

In some areas, mine drainage combines with organic wastes to produce unique and serious water quality problems. Mine drainage problems, primarily along the eastern tributaries of the Allegheny River, are some of the most critical in the Ohio Basin. Low flow supplementation for water quality control is needed especially in upstream watershed and small tributary areas.

A deficiency in opportunities for outdoor recreation, fishing, and hunting exists in the subbasin, particularly in and near the Pittsburgh and Johnstown metropolitan areas.

In order to reduce sediment loads in streams and impounded waters, further efforts are needed to reclaim strip mine areas and to control erosion on agricultural land by conservation, treatment, and management measures.

a. Going Program Accomplishments. - Federal, State and local interests have endeavored to keep pace with development required to solve critical problems and provide for most urgent needs. Efforts have been underway for some time to solve mine drainage problems, reduce erosion, prevent flooding, improve water quality, and also provide for outdoor recreation, sport fishing, hunting, and other demands. Programs for land management and fish and wildlife preservation have been in effect for years. Timber and crop production methods are continually being improved; these, besides increasing land productivity, enhance conditions for retardation of runoff.

Water resource developments existent in 1965 and those to be completed in going programs include 10 Federal reservoirs, 14 major local protection projects, totaling 55 miles in length, four authorized upstream watershed projects, as well as several smaller flood control projects under jurisdiction of local entities. The 10 Federal reservoirs, situated to control about 45 percent of the drainage area, were completed, under construction or in advanced planning as of July 1965. (One is Allegheny Reservoir, the fifth largest lake in the Ohio Basin.) When all are complete, they will provide a total of 1,712,800 acre-feet of storage capacity for flood control, 260,900 acre-feet of storage for low flow supplementation, and 356,300 acre-feet of joint-use space for flood control in the winter and for other purposes in the summer. The four watershed projects cover 492 square miles and include 27 detention structures

with 26,300 acre-feet of flood storage capacity and 27,100 acre-feet for other purposes, as well as 31 miles of channel through agricultural land in the flood plain. The foregoing projects would prevent average annual damages of $23 million under 1965 conditions of development.

Sufficient water generally has been available to meet demand; but by 1980, shortages are expected to arise in meeting the withdrawal demand of 3.3 billion gallons per day, particularly in upstream reaches of the tributaries. There are several impoundments for local water supply, but flowing streams have been the major source for municipal and industrial water. Only 15 percent of the water demand for municipal use is being obtained from ground water sources. Except at Blairsville, Pa., industrial and municipal water demands usually have been satisfied. Water demand by rural communities and that for domestic, livestock, and irrigation use on farms have been met except during periods of prolonged droughts.

The existing system of eight locks and dams, completed in 1938, provides slack water navigation on the Allegheny River for 72 miles between Pittsburgh and East Brady, Pa. Waterborne freight traffic was 63 million ton-miles in 1965. The waterway has a physical, practical capacity to accommodate about 90 million ton-miles of transport annually. This appears to be adequate until after 1980.

The basin is rugged, and hydroelectric power sites are available; however, as of 1965, only one hydroelectric plant, privately owned, of 28,800 kilowatts had been developed and produced but 2 percent of the subbasin's power generation. A pumped-storage hydroelectric facility with a capacity of 325,000 kilowatts is licensed for construction at Kinzua Dam (Allegheny Reservoir) by privately owned utilities.

The Allegheny subbasin has a number of State and local parks and many areas of scenic beauty. In 1960, water related outdoor recreational activity reached 9 million recreation-days. In addition sport fishing and hunting came to 1.8 million angler days and 4.2 million hunter days, respectively.

b. Future Demand. - Municipal and industrial water withdrawals are expected to nearly triple by 2020, increasing from about 493 million gallons per day in 1960 to 1,345 m.g.d. Withdrawals to satisfy electric power cooling requirements are projected to increase eightfold by 2020 to an average of 8.3 billion gallons per day. Demand for water in rural areas was about 50 m.g.d. as inventoried in 1960; by 2020 demand is projected to be about 73 m.g.d.

By the year 2020, waste loads in rivers are projected to increase 2.7 times the 1960 average, and to absorb them without degrading water quality beyond acceptable limits, greater streamflows will be required.

Completion of the going program for flood control would prevent about 90 percent of the potential average annual damages from flood flows with

1965 level of flood plain development. Residual average annual damages under these conditions would be about $2.7 million. Potential flood damages are estimated to be 3 times this amount by 2020 with projected conditions of flood plain development unless additional protection works and management actions are undertaken for their prevention.

Deepening and modernizing the navigable waterway will be required to keep pace with demands for waterborne freight traffic, which is projected to increase by 2020 to 130 million ton-miles or 40 million ton-miles beyond the apparent capability of the existing system.

Additional electric power generation will be required to support industrial expansion and the general growth of the economy. Hydroelectric power development at water control reservoirs and feasible pumped-storage sites can provide peaking capacity for use in conjunction with thermal or nuclear baseload plants. By 2020, it is estimated that hydroelectric power plants could be efficiently utilized to provide about 10 percent of the total capacity requirements in the Ohio Basin.

Land area requiring treatment and proper management for efficient use is projected to increase to nearly 4 million acres by 2020. Sixty thousand acres of strip-mined land are in need of rehabilitation. By 2020, the irrigated land area is projected to increase from 500 to 4,500 acres, whereas land that may be economically drained may reach a total of 143,000 acres.

3. Resource Availability. - The water resource development potential of the Allegheny subbasin is one of the best in the Ohio Basin. Surface runoff is high and reservoir sites are plentiful. Ground water is generally available, and yield is moderate to good in most areas. Water quality in the upper part of the basin is generally good, but coal mining activity near the lower tributaries has polluted many streams.

The rugged topography and lack of major urban or industrial developments in many tributary valleys provide favorable opportunities to develop reservoirs for stream regulation. Seven potential reservoirs have been investigated in some detail and are considered feasible. They could provide about 1.1 million acre-feet of storage that would control nearly 1,600 square miles of drainage area. There are 19 potentially feasible watershed projects containing sites for 112 water detention structures having about 0.5 million acre-feet of reservoir space which would provide control of 885 square miles of upstream watershed area. Potential reservoirs and watershed projects along with those in the going program are shown on the subbasin map, figure AL-1. An accounting of storage capacity for streamflow control is given in table AL-3.

Availability of considerable runoff and storage sites in the Allegheny subbasin makes it a key area for control of flow on the Ohio River. Also resource development will provide opportunities for the satisfaction of demands for outdoor recreation. Considering the proximity of scenic and wooded areas to large metropolitan centers,

tourist recreation activity can be expected to rise in importance if access to attractive locations is improved. Transportation routes are generally east-west oriented, and roads into more remote areas are limited.

There is a substantial potential for ground water development from the glacial sands and gravels in the northwestern part of the subbasin. Bedrock aquifers in the subbasin generally yield moderate to large supplies. Some high-chloride waters are present at relatively shallow depths in some locations and some contamination has occurred in oil-producing areas.

The hydroelectric power potential of the Allegheny subbasin has not been fully investigated; therefore, the amount of feasible hydroelectric power capacity is largely unknown. However, the terrain indicates this may be substantial, particularly for high-head pumped storage power projects, a few of which could utilize the reservoirs of projects for other purposes as upper or lower pools. In addition to the Kinzua pumped-storage facility, which utilizes Allegheny Reservoir, there are two identified locations on the Clarion River where hydroelectric plants are potentially feasible.

4. Assessment of Resource Development Requirements. - Results of the subbasin assessment to determine the magnitude and costs of resource development required to satisfy projected demands for water and related functions and services are summarized in table AL-4.

Principal water supply, water quality and flood problem areas, together with reservoirs and upstream watershed projects in the going program of development, and those identified as potential future projects, are shown on the subbasin map, figure AL-1. Summary data for projects in the going program are given in Appendix K, table 15 through 21, and for identified potential projects in tables 24 through 28. The relationship of problem areas and projects in the going program is shown schematically in figure AL-2, and key data relating to problem areas are given in table AL-2. The schematic diagram was used for general orientation in analyzing problems and needs and establishing development requirements for streamflow control.

a. Requirements To Be Furnished by Identified Resource Potential. - Analysis of demands for water and related functions and services and of the means whereby these demands can be satisfied indicates that to solve water supply, water quality, and flood problems, development of additional storage capacity for streamflow control will be required; also, further local protection projects and channel improvements will be required in several locations, either singly or in combination with streamflow regulation, to better cope with flood problems.

Total storage capacity required to provide streamflow control is estimated to be 1.6 million acre-feet in addition to the amount that will be made available upon completion of the going program. About 1,335,500

acre-feet of reservoir capacity, including 179,900 acre-feet associated with upstream watershed projects, will be required for control of flood-flows. In addition, major local protection works at 4 locations and 19 miles of channel improvements in potential watershed projects will be required. About 141,800 acre-feet of storage capacity will be required to make water available to supplement streamflows during low flow periods. Storage capacity provisions for streamflow supplementation are limited to amounts which are beyond the capability of available surface and ground water sources to satisfy demands for water withdrawals and for flow augmentation in the interest of water quality. The ground water potential is considered adequate to provide 123 million gallons per day toward satisfying 2020 water requirements. Of the total required storage, 667,800 acre-feet would be furnished in identified potential reservoirs and upstream watershed projects.

The capacity of the Allegheny waterway is sufficient to handle waterborne commerce projected for 1980. Before the year 2020, however, increased navigation channel capacity will be needed in the lower 30 miles of the river in order to serve efficiently the increased demand for bulk commodities in the Pittsburgh region. In conjunction with the channel improvement, locking facilities in the reach will need to be replaced with modern structures compatible with the Monongahela and upper Ohio River systems.

The identified hydroelectric power potential of 565,000-kilowatt installed capacity would be useable before 1980 to meet a portion of the growing Ohio Basin power requirements; inclusion of the power potential as an element of water resource development is based on judgment that the installation will prove to be desirable and economically feasible in comparison to alternative sources of power supply.

Total area in potential feasible upstream watershed projects is about 2.4 million acres. Of this amount, it is estimated that approximately a million and a quarter acres of cropland, pasture, and woodland will require treatment and management to enhance land productivity and serve other beneficial purposes. Retardation of runoff, control of erosion, and reduction of sediment transport to streams are important considerations.

The improvement of water quality in the streams and the availability of reservoirs, impoundments, and other developments would provide potential opportunities for over 11.0 million outdoor recreation-days annually if access and facilities are made available.

b. Remaining Requirements. - The 95,500 acre-feet of storage capacity at unidentified sites is required to supplement streamflows during low flow periods. It includes an amount for water required in areas not identified by specific location of need and an amount required to provide stream regulation in several identified areas of need, but for which storage developments are not identified.

Storage capacity that can be made available in identified potential projects is sufficient to provide for subbasin flood control requirements and would also furnish a portion of the capacity required for flood stage reduction on the Ohio River. The 714,000 acre-feet for which additional development will be required is the remaining amount needed in the Allegheny subbasin to assist in regulating the Ohio River Standard Project Flood to the maximum flood stage of record.

New and expanded facilities in the Allegheny subbasin will help supply the water-oriented, recreational needs of the Pittsburgh Standard Metropolitan Statistical Area (SMSA) where resources are relatively lacking. The extent to which demand for outdoor recreational opportunity can be satisfied beyond that provided by identified developments has not been assessed. A portion of the remaining requirement can be met in conjunction with other needed water resource developments in the subbasin. The rest will likely have to be provided by recreation lakes, Federal and State forests, State and local parks, and private development programs. Present deficiencies in hunting opportunities within the subbasin could be partially alleviated by the use of facilities in adjacent basins, particularly the Beaver subbasin, for which a surplus in hunting opportunities is projected through 1980.

Remaining land treatment and management requirements are associated with the general land base outside potential watershed projects, with exception that lands to be irrigated or drained may be located in or outside watershed projects. By the year 2020, approximately 2.4 million acres of cropland, pasture, and woodland would be subject to treatment and management measures, some of the more common being contour farming of all types, controlled grassland farming, and improved forest management and utilization. These lands are accounted for in the general inventory of requirements but are not identified by specific location.

TABLE AL-1

ALLEGHENY SUBBASIN
DEMAND FOR WATER AND RELATED FUNCTIONS AND SERVICES

	Unit	Base Year Amount	Projected Increase(1) 1980	2020
Water Withdrawal				
Municipal and Industrial(2)	Million Gallons Per Day	493.2	166.1	851.8
Electric Power Cooling	Million Gallons Per Day	1,013	3,127	7,287
Rural Communities	Million Gallons Per Day	44.8	5.3	14.5
Rural Domestic and Livestock	Million Gallons Per Day	5.90	0	5.27
Irrigation(3)	Million Gallons Per Day	0.2	0.9	1.9
Stream Assimilation of Organic Waste Effluent(4)	1,000 Population Equivalents	175.6	64.0	301.7
Flood Damage Prevention(5)	Million Dollars Annually	23.34	3.74	9.48
Waterway Freight Movement(6)	Million Ton-Miles Annually	90	0	40
Hydroelectric Power - Installed Capacity	Megawatts	28.8	(Assessed on a basin-wide basis)	
Outdoor Recreation	Million Recreation Days	9.0	17.8	61.8
Sport Fishing	Million Angler Days	1.80	0.16(7)	0.45(7)
Hunting	Million Hunter Days	4.17	0.34(7)	0.50(7)
Commercial Fishing			(Assessed on a basin-wide basis)	
Land Treatment and Management	1,000 Acres	315	1,283	3,626
Drainage	1,000 Acres	81	47	62
Irrigation (Land Area)	1,000 Acres	0.5	1.6	4.0

NOTES:
(1) Base year amounts plus projected increase equals gross demands.

(2) Mining industry water requirements not included; assessed on a basin-wide basis.

(3) Withdrawal shown is for average year; drought year may be 45 percent higher.

(4) Residual biochemical oxygen demand after 85 percent waste removal by treatment.

(5) The dollar amounts (1980 and 2020) are indices to the magnitude of the problem and the protection measures required to reduce the potential damaging effects of floods.

(6) An index to the canalization and waterway facilities required to accommodate the transport of waterborne freight.

(7) Net requirements.

TABLE AL-2

ALLEGHENY SUBBASIN
PRINCIPAL CONSIDERATIONS IN DETERMINING STORAGE CAPACITY REQUIREMENTS
FOR CONTROL OF STREAMFLOW

A. SUPPLEMENTAL STREAMFLOW REQUIRED AT KEY LOCATIONS TO CONTROL WATER QUALITY (CFS).

Problem Area(1)	Stream	Required Flow(2) 1980	2020	Flow Provided by Going Program	Supplemental Flow Required 1980	2020
Jamestown, NY	Cassadaga Creek	40	70	10	30	60
Bradford, Pa	Tunungwant Creek	35	65	10	25	55
Meadville, Pa	French Creek	40	75	35	5	40
Windber, Pa	Paint Creek	24	43	0	24	43
Indiana, Pa	Two Lick Creek	30	40	25	5	15
Latrobe, Pa	Loyalhanna Creek	35	45	15	20	30
Cresson, Pa	Little Conemaugh Creek	17	30	0	17	30

B. WATER REQUIRED TO SATISFY DEMANDS FOR WITHDRAWAL AND USE (IN ADDITION TO THAT PROVIDED IN BASE YEAR) (MGD).

Item	1980	2020
1. Total withdrawal(3)	3,299	8,161
2. To be provided by groundwater	25	123
3. Total consumptive use	52	198

C. FLOOD DAMAGE AREAS.

Location	Residual Damages(4) (Millions Dollars)	
1. Upstream areas	1.16	
2. Major urban areas(1)	0.66	
Jamestown-Falconer, NY, Lake Chatauqua Meadville, Pa, French Creek Dubois, Pa, Sandy Creek Eldred, Pa, Allegheny River		
3. Other flood plain areas	0.90	
4. Total subbasin	2.72	Projected to 3.74 in 1980 and 9.48 in 2020.

NOTES: (1) See figure AL-1 for geographic location of principal problem areas and figure AL-2 for schematic relationship.

(2) Streamflow required to maintain a minimum of 4 parts per million of dissolved oxygen.

(3) Water required to satisfy municipal and industrial, electric power cooling, rural community, rural domestic and livestock, and irrigation demands.

(4) Estimated average annual damages with the 1965 flood control program completed (1965 constant dollars).

TABLE AL-3

ALLEGHENY SUBBASIN
ACCOUNTING OF STORAGE CAPACITY FOR STREAMFLOW CONTROL
(IN ADDITION TO THAT PROVIDED IN THE GOING PROGRAM)

	Time Period 1980	2020
	Storage (1,000 Ac Ft)	
A. WATER QUALITY CONTROL.		
1. Storage required(1)	60.1	111.9
2. Storage provided in identified potential sites	10.7	18.7
3. Additional storage required	49.4	93.2
B. WATER WITHDRAWALS.		
1. Storage required	33.5	154.2
C. FLOOD CONTROL.		
1. Subbasin and Ohio River control requirement	245.1	1,335.5
2. Storage provided in identified potential sites	66.6	621.5
a. *for solving localized problems*	(66.6)	(179.9)
b. effective in controlling both subbasin and Ohio River flows	(0)	(441.6)
3. Additional storage required(2)	178.5	714.0
D. TOTAL STORAGE REQUIREMENT.		
1. Water quality control, water withdrawals, and flood control	338.7	1,601.6
2. *Available in identified potential sites*(3)	96.3	667.8
3. Joint use storage	13.3	124.3
4. Additional storage required(4)	229.1	809.5

NOTES: (1) Storage capacity required to provide supplemental flows at key urban locations and rural communities in upstream watershed areas.

(2) Remaining Allegheny subbasin share of storage required to reduce the Ohio River Basin Standard Project Flood to the maximum flood stage of record.

(3) See figure AL-1.

(4) Terrain indicates storage sites are potentially available.

TABLE AL-4

ALLEGHENY SUBBASIN
SUMMARY ASSESSMENT OF RESOURCE DEVELOPMENT REQUIREMENTS

Program Elements	Unit	Provided in Going Program	Additional Requirement[1] 1980 Amount	1980 Capital Cost ($1,000)	2020 (Accumulative) Amount	2020 (Accumulative) Capital Cost ($1,000)
PART 1. TO BE FURNISHED BY IDENTIFIED RESOURCE POTENTIAL WITHIN SUBBASIN.						
A. Streamflow Control and In-Stream Use						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	617.2	29.7	3,700	46.3	7,900
2. Control of Flood Flows						
a. reservoir and detention storage	1,000 Ac Ft	1,739.1	66.6	10,400	621.5	157,900
b. local protection projects	Miles	55.0	5.7	3,500	(2)	7,500
c. channel improvement	Miles	31	7	200	19	500
3. Navigable Waterway						
a. improvement to existing waterway	Miles of Channel	72	0	0	30	70,000
b. new waterway	Miles of Channel	-	-		-	-
c. channel deepening to 12 feet	Miles of Channel	-	0	0	30	10,000
4. Hydroelectric Power - Installed Capacity	Megawatts	28.8	565	63,600	(Assessed on a Basin-wide Basis)	
B. Related Programs						
1. Outdoor Recreation(3)(4)	Million Recreation Days	9.0	1.7	5,300	11.1	36,300
2. Watershed Project Land Treatment and Management(5)	1,000 Acres	315	515.6	12,900	1,251.8	31,300
	COSTS - PART 1			99,600		321,400
PART 2. REMAINING REQUIREMENTS.						
A. Streamflow Control and In-Stream Use(6)						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	-	50.6	12,900	95.5	24,400
2. Storage for Control of Flood Flows	1,000 Ac Ft	-	178.5	45,500	714.0	182,100
3. Hydroelectric Power				(Assessed on a Basin-wide Basis)		
B. Related Programs						
1. Outdoor Recreation(3)(7)	Million Recreation Days	-	16.1	54,000	50.7	169,700
2. Fish and Wildlife						
a. sport fishing(3)(7)	Million Angler Days	1.80	0.16	600	0.45	1,600
b. hunting(3)(7)	Million Hunter Days	4.17	0.34	1,200	0.50	1,800
c. commercial fishery				(Assessed on a Basin-wide Basis)		
C. Land Treatment and Management						
1. Lands Outside Watershed Projects	1,000 Acres	-	767.9	19,200	2,374.3	59,300
2. Irrigation (Acres to be Irrigated)	1,000 Acres	0.5	2.1	200	4.9	500
3. Drainage	1,000 Acres	81	36.8	6,000	46.7	7,700
	COSTS - PART 2			139,600		447,100
	TOTAL COSTS - (PARTS 1 AND 2)			239,200		768,500

NOTES: (1) Requirement in addition to that provided by going development programs.

(2) Project dimensions not defined at this time.

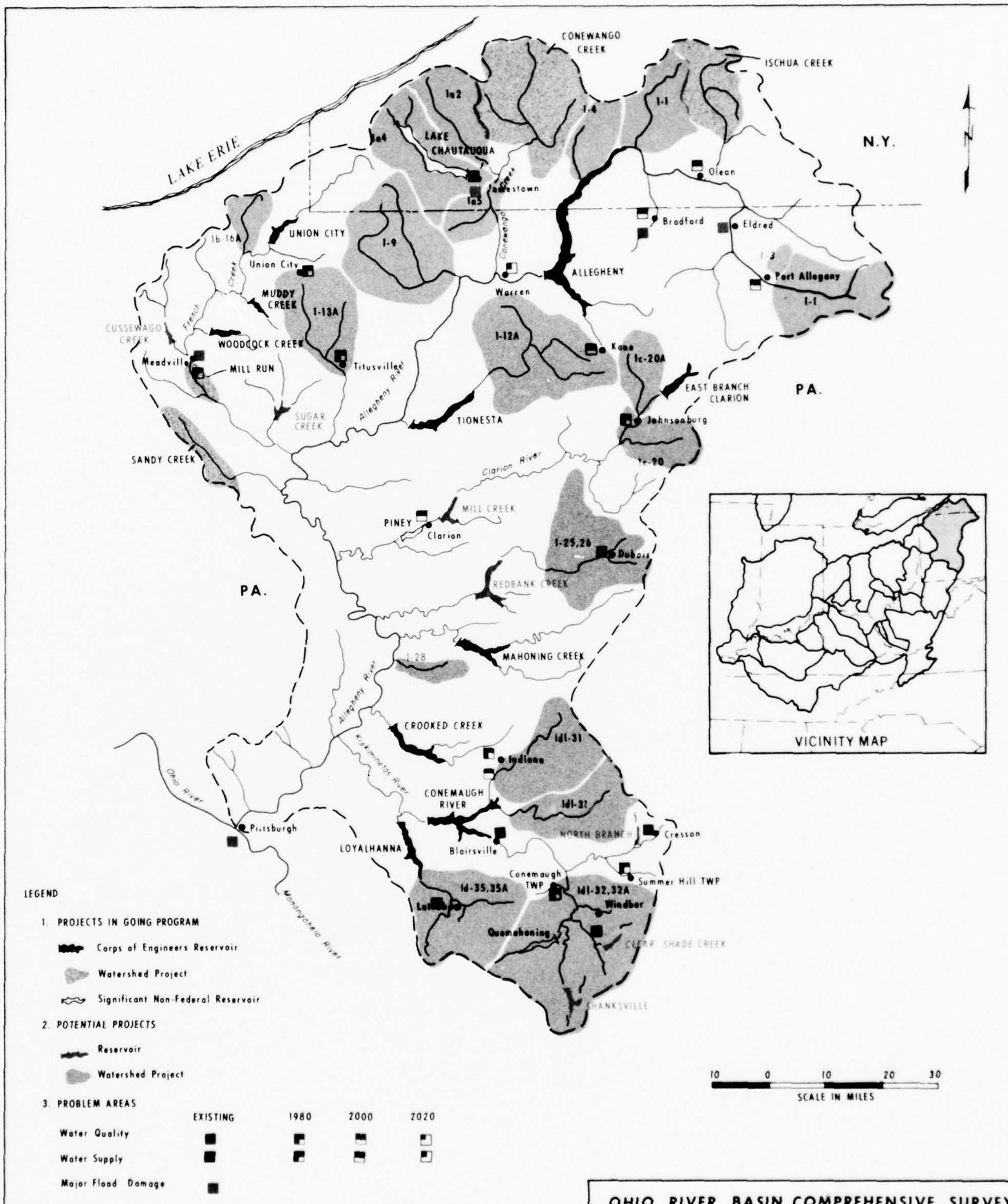
(3) Costs shown are for initial facilities and such measures as may be required to implement the program and do not include water and related land cost. Base year 1960.

(4) The number of outdoor recreation days shown include some sport fishing and hunting which could not be separately accounted for in available data.

(5) Land area and costs shown are for total land treatment and management requirements in watershed projects and cover both water resource development related and other lands.'

(6) Specific sites to provide storage capacity for streamflow control are not identified; however, favorable storage sites are potentially available.

(7) Because of population and resource distributions, remaining subbasin requirements for outdoor recreation, sport fishing and hunting not satisfied by water resource developments may require a trade off with adjacent subbasins or satisfied by other means.



OHIO RIVER BASIN COMPREHENSIVE SURVEY

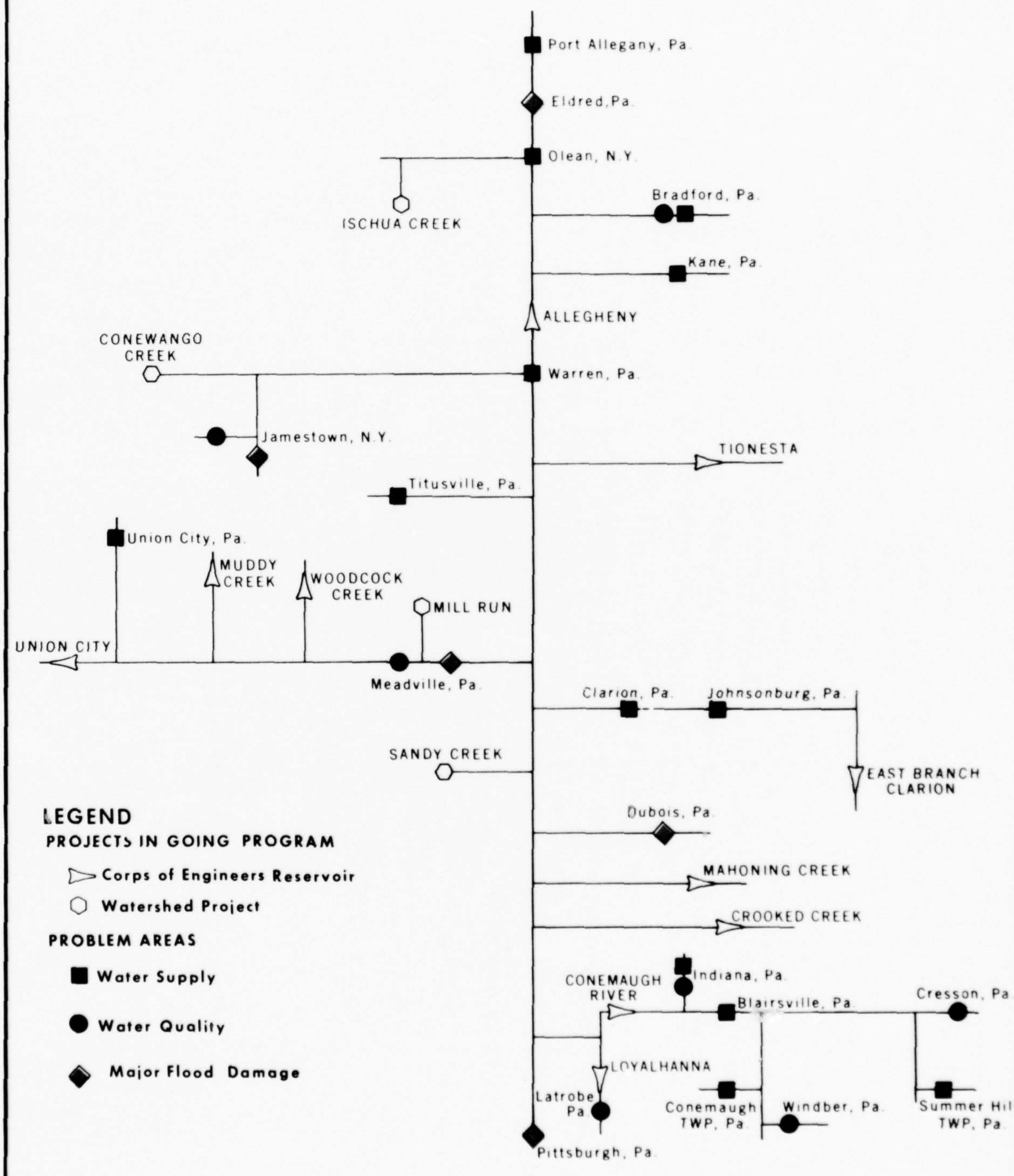
ALLEGHENY SUBBASIN

PRINCIPAL
WATER SUPPLY, WATER QUALITY AND FLOOD PROBLEMS

RESERVOIRS AND WATERSHED PROJECTS
IN GOING PROGRAM, AND POTENTIALS

CORPS OF ENGINEERS
APPENDIX K

U.S. ARMY OHIO RIVER DIVISION
FIGURE A1-1



OHIO RIVER BASIN COMPREHENSIVE SURVEY

ALLEGHENY SUBBASIN
ANALYSIS SCHEMATIC

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE AL-2

MONONGAHELA

1. Planning Environment. The Monongahela subbasin, situated in the northeasterly portion of the Ohio Basin, and the adjacent Allegheny subbasin comprise the headwaters of the Ohio River. The Monongahela subbasin covers about 7,400 square miles, or nearly five percent of the Ohio Basin study area. It includes portions of southwestern Pennsylvania, northern West Virginia, and the westernmost tip of Maryland. The topography is rolling ro rugged with much of the land heavily forested. The growing season is one of the shortest in the Ohio Basin.

The subbasin has a history of recurring heavy winter snowfall and also summer thunderstorms with intense rainfall. Heavy rains from hurricane-influenced storms may occur infrequently. Annual average runoff of 23.1 inches is greater than that for the Ohio Basin. The subbasin contributes about 40 percent of the Ohio River annual flow at Pittsburgh and five percent of the flow at Cairo, Illinois. During peak runoff periods high flows contribute materially to Pittsburgh and Ohio River flood problems. In contrast, extended droughts, although infrequent, have caused major crop losses and acute water shortages.

The Monongahela subbasin, doorway to the early-day western frontier, was settled in the late 1700's. Some of the early immigrants settled in isolated portions of the highlands where rich soils and bountiful forests and wildlife made conditions ideal for a self-contained economy. Many small urban centers stemmed from this early beginning. Other migrants settled in the area adjacent to the confluence of the Monongahela and Allegheny Rivers. Here Pittsburgh grew rapidly and today is one of the major industrial and commercial centers of the nation, and the largest metropolitan center (2.4 million people) in the Ohio Basin.

The subbasin contains large commercial coal deposits. A considerable portion of the economy, including steel producing and related industries, is based on this resource. The Monongahela Basin, excluding the Pittsburgh metropolitan portion, has about three percent of the population in the Ohio study region, 2.6 percent of the labor force and produces over eight percent of the industrial output. Economic projections indicate that the general economy of the Monongahela Basin will continue to grow but at a lesser rate than for the overall Ohio Basin.

2. Demand for Water and Related Functions and Services. More intense use, additional development and more efficient management of water and related land resources along with diligent prosecution of other programs allied to water and land use will be required to keep pace with projected demands for water and related functions and services in the Monongahela subbasin. Base year and projected increases that comprise gross demands for water and related functions and services are shown in table MO-1. Principal considerations in determining storage capacity requirements for control of streamflow are provided in table MO-2.

Approximately 97 percent of the demand for municipal and industrial water supply is concentrated in the highly industrialized lower portion of the Monongahela subbasin. This represents nearly 45 percent of the total demand in the Ohio River Baisn. In general, present water supplies are adequate in quantity and, if properly controlled, will be sufficient to satisfy future demand; but the quality of surface waters and, in some cases, ground water is substandard for many uses.

Water quality is a major concern in the Monongahela subbasin. The concentration of economic activity has resulted in the aggravation of problems associated with municipal and industrial waste, and other stream pollution. Drainage from active and abandoned mines situated throughout the basin has degraded much of the surface water in the basin.

Flooding is still a problem at several locations and Pittsburgh has experienced higher average annual damages than any other city in the Ohio Basin. Although a considerable portion of the Pittsburgh water resource demands and problem solutions are in the Monongahela subbasin, Pittsburgh is included in the report in the upper Ohio River area.

There are large coal reserves in the basin. The mining industry, together with the steel-producing and related industries, rely heavily on the availability of low-cost transportation for the transport of bulk commodities. The interrelation of the mining within the basin with industries both within the Monongahela and nearby basins will require improvement of the waterway system to handle movement of waterborne freight economically and efficiently.

Outdoor water-based recreation facilities are insufficient to serve the people of the Pittsburgh metropolitan area. If predicted future recreational desires are to be satisfied, further sources of opportunity will be required.

a. Going Program Accomplishment. Federal, state and local interests have endeavored to keep pace with development required to solve critical problems and provide for most urgent needs. Efforts have been underway for some time to solve mine drainage problems, reduce erosion, prevent flooding, improve water quality, improve the navigable waterway and provide for outdoor recreation, sport fishing, hunting and other demands. Programs for land management, and fish and wildlife preservation have been in effect for years. Timber and crop production methods are continually being improved; these, in addition to increasing land productivity, help retard runoff.

There are two existing Federal multiple-purpose reservoirs in the basin. These provide a total of 429,000 acre-feet of storage for flood control, 97,800 for low flow supplementation and 151,400 acre-feet of joint use reservoir capacity for winter flood control and summer low flow supplementation. These reservoirs control about 22 percent of the subbasin area. There are seven authorized upstream watershed projects covering 124 square

miles of the subbasin. These projects include 30 upstream detention structures and 16 miles of channel improvement. Ten Federal and numerous non-Federal local protection projects, with floodwalls, levees and channel improvements in varying degree, further control damaging flood flows. The foregoing projects would prevent average annual flood damages of 8.4 million dollars. Construction of the authorized Rowlesburg and Stonewall Jackson Reservoirs appears to be likely in the near future. These reservoirs would control runoff from an additional 14 percent of drainage area and would provide 337,600 acre-feet of storage capacity for flood control, and 569,300 for other purposes. Recreational facilities are also contemplated.

Flowing streams within the basin have been tapped as the principal source of major municipal and industrial water supplies. Existing impoundments for water supply, in most cases, are associated with the provision of small public sources of supply.

There are two privately-owned hydroelectric generating plants in the basin with a total capacity of 70 megawatts. A pumped storage hydroelectric power installation of 525 megawatts at the Federally authorized Rowlesburg project is being investigated by a private utility under a preliminary permit issued by the Federal Power Commission.

After completion of the going program, nine locks and dams will provide 129 miles of navigable waterway on the Monongahela River which can accommodate 1.8 billion ton-miles of waterborne freight annually.

Recreation facilities at reservoirs, watershed projects and national forests and along natural streams have been provided by Federal and non-Federal interests. More than 30 state parks, forests and recreation areas exist in the basin. In 1960, water related recreational activity amounted to 2.5 million recreation days, 368,400 angler days and 1.8 million hunter days.

b. Future Demand. It will be noted in table MO-1 that water withdrawal demands that existed in 1960 will more than double by 2020, increasing from about 5,900 million gallons per day to over 16,000 m.g.d.

Organic waste loads entering streams are projected to increase about two times the 1960 average by 2020. These waste loads are the remaining residual after secondary treatment or equivalent reduction of industrial waste had been applied.

Assuming 1965 level of flood plain development, about 63 percent of the potential average annual damages from flood flows would be prevented after completion of the going program for flood control. Under these conditions, 45 percent of the basin flood plain area would be unprotected, and of the area protected 33 percent would need additional protection. These areas are subject to future development due to the limited valley lands in flood-free areas. Protection works and management programs will be needed to prevent potential flood damages 2.7 times the 1965 annual average with projected conditions of flood plain development.

Deepening and improvement of the navigable waterway will be required to keep pace with demands for waterborne freight traffic, which is projected to increase by 2020 to 25 billion ton-miles or 700 million ton-miles beyond the capability of the system after going program completion.

Additional electric power generation will be required to support industrial expansion and the general growth of the economy. Hydroelectric power development at water control reservoirs and feasible pumped-storage sites can provide peaking capacity for use in conjunction with thermal baseload plants. By 2020, it is estimated that hydroelectric power plants could be efficiently utilized to provide about 10 percent of the total capacity requirements in the Ohio Basin.

Land area requiring treatment and proper management for efficient use is projected to increase to about 2.3 million acres by 2020. About 58,000 acres of strip mined lands are in need of rehabilitation. By 2020, the irrigated land area is projected to increase from 200 to 1,900 acres, whereas land that may be economically drained may reach a total of 148 thousand acres.

The demand for outdoor recreational opportunities is predicted to increase in excess of 17 times the 1960 average by 2020. This demand, in conjunction with increased pressure for hunting and fishing opportunity, will require full use of water and lands affiliated with water resource development.

3. Resources Availability. The water resource development potential of the Monongahela Basin is one of the best in the Ohio Basin. Surface runoff is high, reservoir sites are plentiful and ground water supplies are good in most areas. However, to make maximum use of surface water, steps must be taken to control mine drainage which has degraded the quality of streams in many areas.

The rugged topography and lack of major urban or industrial developments in the tributary valley areas provide favorable opportunities to develop stream regulation reservoirs. Six potential reservoirs, in addition to the two that are authorized, have been investigated in some detail and are currently considered feasible. There are 18 potentially feasible watershed projects containing sites for 148 detention structures which would provide control of 622 square miles of upstream watershed areas. Potential reservoirs and watershed projects along with those in the going programs are shown on the subbasin map, figure MO-1.

Ground water in large supplies is available in the eastern mountainous area and along the lower Monongahela and Youghiogheny Rivers. In the central part of the basin aquifers are erratic, but large yields can be developed in some areas. The western third of the basin, however, lacks good aquifers, and conservation of surface waters will be required for water supply.

Extensive scenic and wooded areas are available in the basin for outdoor recreation development and wildlife management, and if access to

attractive locations is improved, recreational opportunity can be considerably enhanced.

The hydroelectric power potential of the Monongahela subbasin has not been fully investigated; therefore, the amount of feasible hydroelectric power capacity is largely unknown. However, the terrain indicates this might be substantial, particularly for high-head pumped-storage power projects, a few of which could utilize the reservoirs of projects for other purposes as upper or lower pools. In addition to the pumped-storage facility being investigated at the Rowlesburg project, there are eight identified locations in the basin where hydroelectric plants are potentially feasible.

4. Assessment of Resource Development Requiremnts. Principal water supply, water quality and flood problem areas, together with reservoirs and upstream watershed projects in the going program of development, and those identified as potential future projects, are shown on the subbasin map, figure MO-1. Summary data for projects in the going program are given in Appendix K, tables 15 through 21 and for identified potential projects in tables 24 through 28. The relationship of problem areas and projects in the going program is shown schematically in figure MO-2, and key data relating to problem areas are given in table MO-2. The schematic diagram was used for general orientation in analyzing problems and needs and establishing development requirements for streamflow control. An accounting of storage capacity for streamflow control is given in table MO-3. Results of the subbasin assessment to determine the magnitude and costs of resource development required to satisfy projected demands for water and related functions and services are summarized in table MO-4.

a. Requirements to be Furnished by Identified Resource Potential. Analysis of demands for water and related functions and services and of the means whereby these demands can be satisfied indicates that to solve water supply, water quality, and flood problems, development of additional storage capacity for streamflow control will be required; also, further local protection projects and channel improvements will be required in several locations, either singly or in combination with streamflow regulation, to better cope with flood problems.

Total storage capacity required to provide streamflow control is estimated to be 2.8 million acre-feet in addition to the amount that will be made available upon completion of the going program. Of this amount, about 1,062,600 acre-feet of reservoir capacity, including 111,300 acre-feet associated with upstream watershed projects, can be provided by the identified resource potential for control of floodflows. In addition, 12.4 miles of local protection and channel improvements are identified. About 657,800 acre-feet of identified storage capacity can be provided to make water available to supplement streamflows during low flow periods. The foregoing amounts of storage capacity include joint use of 212,500 acre-feet of reservoir space. Storage capacity provisions for streamflow supplementation are limited to amounts which are beyond the capability of

available surface flows and ground water sources to satisfy demands. The ground water potential is considered adequate to provide 148 million gallons per day toward satisfying 2020 water requirements.

With completion of the going program for navigation, the capacity of the Monongahela waterway will be sufficient to handle waterborne commerce projected for 1980. Contingent with the deepening of the Ohio River waterway, a channel of comparable depth will be needed on the Monongahela River to move the tonnage of river freight projected for 2020 efficiently. Widening of the channel in the upper end of the system would also be required by that time.

The identified hydroelectric power potential of 1,222 megawatts installed capacity should be useable before 1980 to meet a portion of the growing Ohio Basin power requirements; inclusion of the power potential as an element of water resource development is based on judgment that the installation will prove to be desirable and economically feasible in comparison to alternative sources of power supply.

Total area in potentially feasible upstream watershed projects is about 1.2 million acres. Of this amount, it is estimated that approximately 750,000 acres of cropland, pasture, and woodland will require treatment and management to enhance land productivity and serve other beneficial purposes. Retardation of runoff, control of erosion, and reduction of sediment transport to streams are important considerations.

The improvement of water quality in the streams and the availability of reservoirs, impoundments, and other developments would provide potential opportunities for over 11 million outdoor recreation days annually if access and facilities are made available.

b. Remaining Requirements. The 605,700 acre-feet of storage capacity required to supplement streamflows during low flow periods includes an amount for water required in areas not identified by specific location of need and an amount required to provide stream regulation in several identified areas of need, but for which storage developments are not identified.

Storage capacity that can be made available in identified potential projects is sufficient to provide for subbasin flood control requirements and would also furnish a portion of the capacity required for flood stage reduction on the Ohio River. The 254,000 acre-feet for which additional development will be required is the remaining amount needed in the Monongahela subbasin to assist in regulating the Ohio River Standard Project Flood to the maximum flood stage of record.

New and expanded facilities in the Monongahela Basin will help supply the water-oriented, recreational needs of the Pittsburgh Standard Metropolitan Statistical Area (SMSA) where resources are relatively lacking. The extent to which demand for outdoor recreation, hunting and

fishing opportunity can be satisfied beyond that provided by identified developments has not been assessed. A portion of the remaining requirement can be met in conjunction with other needed water resource developments in the subbasin. The rest will likely have to be provided by single-purpose recreation lakes, State and local parks, and private developments.

Remaining land treatment and management requirements are associated with the general land base outside watershed projects, with the exception that lands to be irrigated or drained may be located in or outside watershed projects. By the year 2020, approximately 1.5 million acres of cropland, pasture, and woodland would be subject to treatment and management measures, some of the more common being contour farming of all types, controlled grassland farming, and improved forest management and utilization. These lands are accounted for in the general inventory of requirements but are not identified by specific location.

TABLE MO-1

MONONGAHELA SUBBASIN
DEMAND FOR WATER AND RELATED FUNCTIONS AND SERVICES

	Unit	Base Year Amount	Projected Increase (1) 1980	Projected Increase (1) 2020
Water Withdrawal				
Municipal and Industrial (2)	Million Gallons Per Day	4,859.2	885.3	5,475.8
Electric Power Cooling	Million Gallons Per Day	1,013	827	4,797
Rural Communities	Million Gallons Per Day	31.0	8.0	21.4
Rural Domestic and Livestock	Million Gallons Per Day	4.52	0	3.43
Irrigation (3)	Million Gallons Per Day	0.1	0.3	0.8
Stream Assimilation of Organic Waste Effluent (4)	1,000 Population Equivalents	136.3	20.0	126.7
Flood Damage Prevention (5)	Million Dollars Annually	8.40	6.47	13.53
Waterway Freight Movement (6)	Million Ton-Miles Annually	1,800	100	700
Hydroelectric Power - Installed Capacity	Megawatts	70.4	(Assessed on a basin-wide basis)	
Outdoor Recreation	Million Recreation Days	2.5	14.2	41.5
Sport Fishing	Million Angler Days	0.37	0.04 (7)	0.15 (7)
Hunting	Million Hunter Days	1.80	0.51 (7)	0.80 (7)
Commercial Fishing			(Assessed on a basin-wide basis)	
Land Treatment and Management	1,000 Acres	79	851	2,243
Drainage	1,000 Acres	84	45	64
Irrigation (Land Area)	1,000 Acres	0.2	0.7	1.7

NOTES:
(1) Base year amounts plus projected increase equals gross demands.

(2) Mining industry water requirements not included; assessed on a basin-wide basis.

(3) Withdrawal shown is for average year; drought year may be 45 percent higher.

(4) Residual biochemical oxygen demand after 85 percent waste removal by treatment.

(5) The dollar amounts (1980 and 2020) are indices to the magnitude of the problem and the protection measures required to reduce the potential damaging effects of floods.

(6) An index to the canalization and waterway facilities required to accommodate the transport of waterborne freight.

(7) Net requirements.

TABLE MO-2

MONONGAHELA SUBBASIN
PRINCIPAL CONSIDERATIONS IN DETERMINING STORAGE CAPACITY REQUIREMENTS
FOR CONTROL OF STREAMFLOW

A. SUPPLEMENTAL STREAMFLOW REQUIRED AT KEY LOCATIONS TO CONTROL WATER QUALITY (CFS).

Problem Area(1)	Stream	Required Flow(2) 1980	Required Flow(2) 2020	Flow Provided by Going Program	Supplemental Flow Required 1980	Supplemental Flow Required 2020
Pittsburgh, Pa	Monongahela River	2,700	4,450	1,820	880	2,630
Clarksburg, W Va	West Fork River	30	50	2	28	48
Weston, W Va	West Fork River	5	10	0	5	10
Uniontown, Pa	Redstone Creek	10	20	1	9	19
Bridgeport, W Va	Beards Run	5	10	0	5	10
Mannington, W Va	Buffalo Creek	5	10	0	5	10
Waynesburg, Pa	South Fork Ten Mile Creek	5	10	0	5	10
Elkins, W Va	Tygart River	5	10	0	5	10
Buckhannon, W Va	Buckhannon River	5	10	0	5	10
Greensburg, Pa	Jacks Run	35	50	1	34	49
Jeannette, Pa	Brush Creek	15	25	1	14	24
Irwin, Pa	Brush Creek	5	10	0	5	10
Scottdale, Pa	Jacobs Creek	5	10	0	5	10
Somerset, Pa	Coxes Creek	5	10	0	5	10
Bentleyville, Pa	Pigeon Creek	5	10	0	5	10

B. WATER REQUIRED TO SATISFY DEMANDS FOR WITHDRAWAL AND USE (IN ADDITION TO THAT PROVIDED IN BASE YEAR) (MGD).

Item	1980	2020
1. Total withdrawal(3)	1,721	10,298
2. To be provided by groundwater	24	148
3. Total consumptive use	18	289

C. FLOOD DAMAGE AREAS.

Location	Residual Damages(4) (Millions Dollars)	
1. Upstream areas	3.58	
2. Major urban areas(1)	0.86	
Clarksburg, W Va, West Fork River Weston, W Va, West Fork River Uniontown, Pa, Redstone and Coal Lick Creeks		
3. Other flood plain areas	0.50	
4. Total subbasin	4.94	Projected to 6.47 in 1980 and 13.53 in 2020.

NOTES:
(1) See figure MO-1 for geographic location of principal problem areas and figure MO-2 for schematic relationship.

(2) Streamflow required to maintain a minimum of 4 parts per million of dissolved oxygen.

(3) Water required to satisfy municipal and industrial, electric power cooling, rural community, rural domestic and livestock, and irrigation demands.

(4) Estimated average annual damages with the 1965 flood control program completed (1965 constant dollars).

TABLE MO-3

MONONGAHELA SUBBASIN
ACCOUNTING OF STORAGE CAPACITY FOR STREAMFLOW CONTROL
(IN ADDITION TO THAT PROVIDED IN THE GOING PROGRAM)

	Time Period 1980	Time Period 2020
	Storage (1,000 Ac Ft)	
A. WATER QUALITY CONTROL.		
1. Storage required(1)	208.5	575.5
2. Storage provided in identified potential sites	171.7	510.7
3. Additional storage required	36.8	64.8
B. WATER WITHDRAWALS.		
1. Storage required	146.4	900.5
C. FLOOD CONTROL.		
1. Subbasin and Ohio River control requirement	456.7	1,316.6
2. Storage provided in identified potential sites	393.2	1,062.6
a. for solving localized problems	(55.6)	(111.3)
b. effective in controlling both subbasin and Ohio River flows	(337.6)	(951.3)
3. Additional storage required(2)	63.5	254.0
D. TOTAL STORAGE REQUIREMENT.		
1. Water quality control, water withdrawals, and flood control	811.6	2,792.6
2. Available in identified potential sites(3)	711.3	1,720.4
3. Joint use storage	36.8	212.5
4. Additional storage required(4)	63.5	859.7

NOTES: (1) Storage capacity required to provide supplemental flows at key urban locations and rural communities in upstream watershed areas.

(2) Remaining Monongahela subbasin share of storage required to reduce the Ohio River Basin Standard Project Flood to the maximum flood stage of record.

(3) See figure MO-1.

(4) Terrain indicates storage sites are potentially available.

TABLE MO-4

MONONGAHELA SUBBASIN
SUMMARY ASSESSMENT OF RESOURCE DEVELOPMENT REQUIREMENTS

Program Elements	Unit	Provided in Going Program	Additional Requirement (1) 1980 Amount	1980 Capital Cost ($1,000)	2020 (Accumulative) Amount	2020 Capital Cost ($1,000)
PART 1. TO BE FURNISHED BY IDENTIFIED RESOURCE POTENTIAL WITHIN SUBBASIN.						
A. Streamflow Control and In-Stream Use						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	249.2	318.1	79,000	657.8	165,300
2. Control of Flood Flows						
a. reservoir and detention storage	1,000 Ac Ft	436.8	393.2	105,800	1,062.6	269,600
b. local protection projects	Miles	13.0	2.4	1,100	(2)	5,300
c. channel improvement	Miles	16	5	800	10	1,600
3. Navigable Waterway						
a. improvement to existing waterway	Miles of Channel	131	131	124,000	131	124,000
b. new waterway	Miles of Channel	-	-	-	-	-
c. channel deepening to 12 feet	Miles of Channel	-	0	0	131	30,000
4. Hydroelectric Power - Installed Capacity	Megawatts	70.4	1,222	137,500	(Assessed on a Basin-wide Basis)	
B. Related Programs						
1. Outdoor Recreation (3)(4)	Million Recreation Days	2.5	2.0	8,300	8.6	32,500
2. Watershed Project Land Treatment and Management (5)	1,000 Acres	79	375.0	9,400	750.0	18,700
COSTS - PART 1				465,900		647,000
PART 2. REMAINING REQUIREMENTS.						
A. Streamflow Control and In-Stream Use (6)						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	-	0	0	605.7	154,400
2. Storage for Control of Flood Flows	1,000 Ac Ft	-	63.5	16,200	254.0	64,800
3. Hydroelectric Power				(Assessed on a Basin-wide Basis)		
B. Related Programs						
1. Outdoor Recreation (3)(7)	Million Recreation Days	-	12.2	41,900	32.9	112,400
2. Fish and Wildlife						
a. sport fishing (3)(7)	Million Angler Days	0.37	0.04	100	0.15	500
b. hunting (3)(7)	Million Hunter Days	1.80	0.51	1,800	0.80	2,800
c. commercial fishery				(Assessed on a Basin-wide Basis)		
C. Land Treatment and Management						
1. Lands Outside Watershed Projects	1,000 Acres	-	476.2	11,900	1,492.5	37,300
2. Irrigation (Acres to be Irrigated)	1,000 Acres	0.2	1.1	100	2.5	200
3. Drainage	1,000 Acres	84	45.2	6,600	48.9	7,200
COSTS - PART 2				78,600		379,600
TOTAL COSTS - (PARTS 1 AND 2)				544,500		1,026,600

NOTES:

(1) Requirement in addition to that provided by going development programs.

(2) Project dimensions not defined at this time.

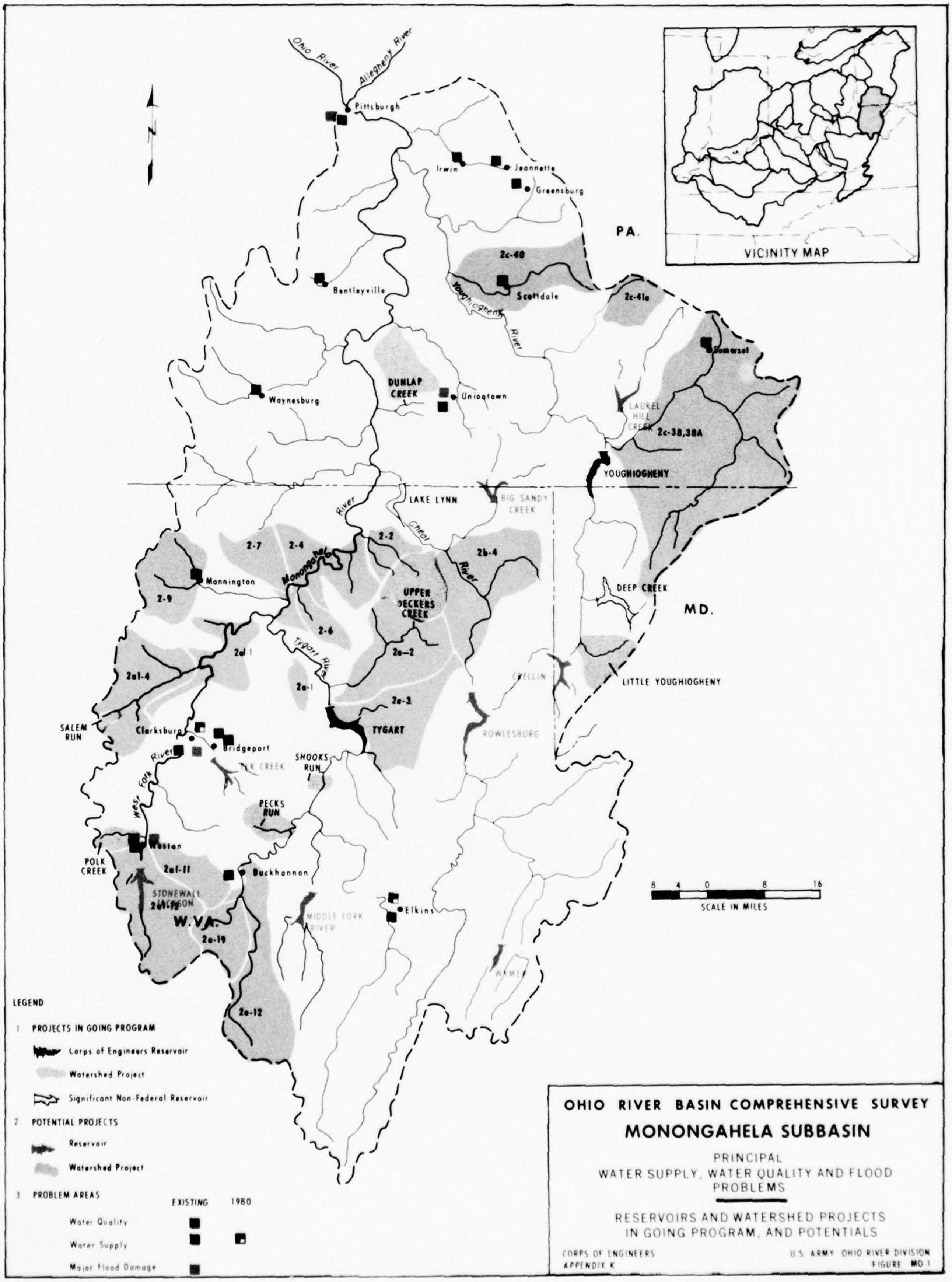
(3) Costs shown are for initial facilities and such measures as may be required to implement the program, and do not include water and related land cost. Base year 1960.

(4) The number of outdoor recreation days shown include some sport fishing and hunting which could not be separately accounted for in available data.

(5) Land area and costs shown are for total land treatment and management requirements in watershed projects and cover both water resource development related and other lands.

(6) Specific sites to provide storage capacity for streamflow control are not identified; however, favorable storage sites are potentially available.

(7) Because of population and resource distributions, remaining subbasin requirements for outdoor recreation, sport fishing and hunting not satisfied by water resource developments may require a trade off with adjacent subbasins or satisfied by other means.



OHIO RIVER BASIN COMPREHENSIVE SURVEY

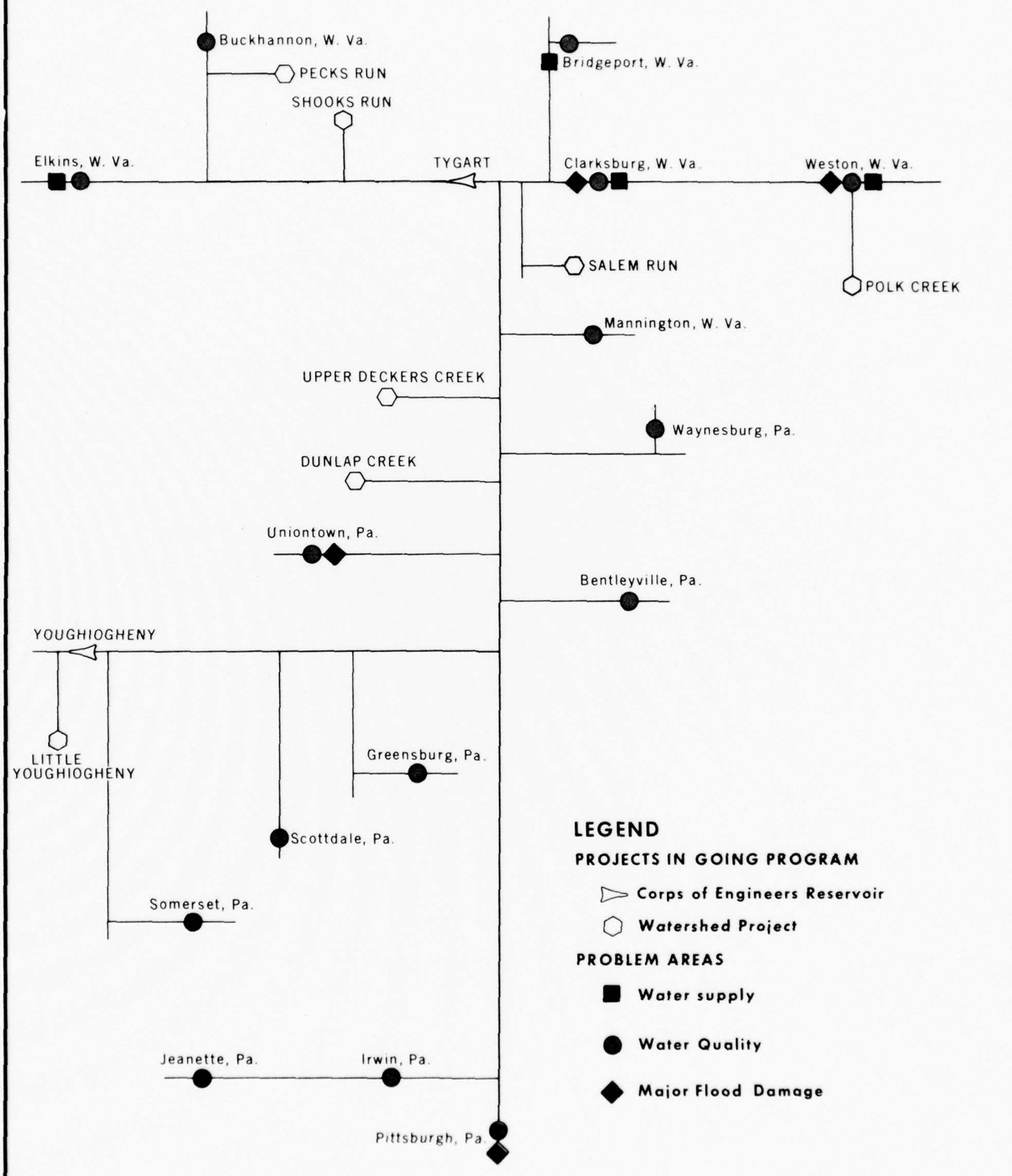
MONONGAHELA SUBBASIN

PRINCIPAL
WATER SUPPLY, WATER QUALITY AND FLOOD PROBLEMS

RESERVOIRS AND WATERSHED PROJECTS
IN GOING PROGRAM, AND POTENTIALS

CORPS OF ENGINEERS
APPENDIX K

U.S. ARMY OHIO RIVER DIVISION
FIGURE MO-1



OHIO RIVER BASIN COMPREHENSIVE SURVEY

MONONGAHELA SUBBASIN
ANALYSIS SCHEMATIC

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE MO-2

BEAVER

1. Planning Environment. The Beaver River subbasin, situated in northeastern Ohio and northwestern Pennsylvania, contains 3,130 square miles, or about two percent of the Ohio Basin study area. The topography is rolling to flat with much of the land in crops and pasture. The climatic history of the subbasin indicates winter snowfall greater than the Ohio Basin average and frequent summer thunderstorms with intense rainfall. However, annual runoff is less than the average for the Ohio Basin. Extended droughts, although infrequent, have caused major crop losses and acute water shortages.

The Beaver subbasin was part of the territory settled in the late 1700's by the Connecticut Land Company. The soil was rich and the forests and wildlife abundant, giving a basis for independent survival. Small urban centers and rural communities stemmed from this early beginning. Migrants concentrated in and near the Lower Mahoning and Shenango River Valleys. The economy of the area grew rapidly and today is highly industrialized. The Mahoning River from Warren to its junction with the Beaver River is lined with industrial plants. This area has often been called the "Little Ruhr" of America. The subbasin currently has nearly 900,000 inhabitants concentrated primarily in the Youngstown metropolitan area.

The basin contains bog ores, coal deposits and limestone. Consequently, a considerable portion of the economy has developed around the steel producing and related industries. The Beaver subbasin has about five percent of the labor force and produces 5.7 percent of the Ohio Basin's industrial output. Projective economic studies of the Ohio Basin indicate that the general economy of the Beaver subbasin will experience growth in the mechanical and electrical machinery trades. However, employment in the primary metals sector is expected to decrease due to productivity increases per worker. Unless alternative employment is supplied, substantial emigration of these skilled workers is indicated through 1980. The population of the basin is expected to continue to grow, but at a lesser rate than for the overall Ohio Basin.

2. Demand for Water and Related Functions and Services. Base year and projected increases that comprise gross demands for water and related functions and services are listed in table BE-1. Principal considerations in determining storage capacity requirements for control of streamflow are provided in table BE-2.

The concentration of economic activity from Warren and on downstream to Youngstown and beyond has not only resulted in large demands for water, flood control, navigation, recreation, and other water oriented functions and services, but also has resulted in the aggravation of problems associated with municipal and industrial waste and other stream pollution. Heat from industrial operations and thermal electric generating plants situated along the streams of the basin have caused serious water temperature problems. More than half of the subbasin's organic waste loads originate in the

vicinity of Youngstown. Improvement of water quality is a major concern throughout the Beaver subbasin.

Flooding is still a problem at many locations along the industrial reaches of the Mahoning and Shenango Rivers and throughout the length of the Beaver River. Measures to control erosion and reduce flood damages are needed in upstream watershed and downstream floodplain areas.

Land treatment and management, drainage and irrigation are needed to increase agricultural productivity and increase rural income.

The people of the Beaver Basin are in need of additional outdoor water-based recreation facilities. If projected future recreational, hunting and fishing desires are to be satisfied, further sources of opportunity will be needed.

a. Going Program Accomplishment. Development and management programs instituted by Federal, state and local interests have generally solved the critical problems and provided for most urgent needs. A policy of cooperation and coordination between the State of Ohio and the Commonwealth of Pennsylvania has been followed to develop the subbasin's water and related land resources.

In 1965, there were two existing Federal multiple-purpose reservoirs in the basin and two under construction. In total, they will provide 302,900 acre-feet of storage for control of floods during the winter season, 30,400 acre-feet for water supply, 114,000 acre-feet for low flow supplementation and 75,400 acre-feet of storage in joint use for winter flood control and for other purposes in the summer. Runoff from about 35 percent of the total basin area would be controlled. The Pymatuning multiple-purpose reservoir, built by the Commonwealth of Pennsylvania, contains 84,000 acre-feet of flood control storage. Two watershed projects, which cover about 120 square miles and include ten structures, have been authorized, one of which is completed. Two Federal and one non-Federal local protection projects further control damaging flood flows. Pymatuning Reservoir and the City of Youngstown's Milton Reservoir have a combined storage of 79,000 acre-feet for low flow supplementation. The 30,675 acre-feet of capacity in the non-Federal Meander Creek Reservoir is regulated to meet requirements of the Mahoning Valley Sanitation District. Flow regulation to increase streamflows during low flow periods has aided materially in reducing temperature problems in the Warren to Youngstown reach of the Mahoning River. Flood damage prevention afforded by flood control projects, when all are completed, will be about 13.3 million dollars.

Sufficient water generally has been available to meet demand; but by 1980, shortages are expected to arise, particularly in the Warren-Youngstown reach of the Mahoning River. There are numerous impoundments for local water supply; however, flowing streams have been the major source for municipal

and industrial water. Water demand by rural communities and that for domestic, livestock, and irrigation use on farms have been met except during periods of prolonged droughts. Smaller communities and rural needs are served primarily from ground water.

As of 1965, there were no hydroelectric power plants in the subbasin.

The Beaver River and its tributaries have not been developed to accomodate waterborne freight traffic.

Recreation facilities at storage sites and along natural streams have been provided by Federal and non-Federal interests. Several state parks, forests and recreation areas exist in the basin. Development and management programs have been put into effect to improve land cover and provide facilities for recreation, hunting and fishing throughout the basin. Even so, the provision of opportunity for outdoor recreation has not kept pace with demand. In 1960, outdoor recreational activity totaled 1.8 million recreation days, and fishing and hunting 910,000 angler days and 510,000 hunter days, respectively.

b. Future Demand. Municipal and industrial water withdrawals are projected to increase over 2.5 times by 2020, increasing from slightly more than 1 billion gallons per day in 1960 to 2.6 billion gallons per day. Withdrawals to satisfy electric power cooling requirements are expected to increase 40 percent by 2020 to an average of 660 million gallons per day. Demand for water in rural areas was about 29 m.g.d. as inventoried in 1960; by 2020 demand is projected to be about 40 m.g.d., or a moderate increase of 35 percent.

By the year 2020, waste loads in rivers are projected to increase about 2.2 times the 1960 average, and to absorb them without degrading water quality beyond acceptable limits, greater streamflows will be required.

About 85 percent of the potential average annual damages from flood flows would be prevented by flood control works in the going program. However, much of the basin flood plain area is unprotected or needs additional protection. Protection works and management programs will be needed to prevent potential flood damages three times the 1965 residual annual average with conditions of flood plain development projected for 2020.

Based on recent studies, 3.5 billion ton-miles of freight would move by 2020 on the subbasin section of a potential new waterway linking the Ohio River and Lake Erie.

Additional electric power generation will be required to support industrial expansion and the general growth of the economy. By 2020, it is estimated that hydroelectric power plants could be efficiently utilized to

provide about 10 percent of the total capacity requirements in the Ohio Basin. The amount that can be supplied will vary by subbasin.

By 2020, land area requiring treatment and proper management for efficient use is projected to increase 737,000 acres over and above that taken care of in upstream watershed projects in the going program. Approximately eighteen thousand acres of strip-mined land are in need of rehabilitation. By 2020, the irrigated land area is projected to increase from 500 to 2,500 acres, whereas land that may be economically drained may increase 131,000 acres over the 1960 base year amount.

The demand for outdoor recreational opportunities is predicted to increase an additional 46.2 million recreation days by 2020 or nearly 27 times that supplied in 1960. This demand, in conjunction with increased pressure for hunting and fishing opportunity, will require full use of water and lands affiliated with water resource development.

3. Resources Availability. The water resource development potential of the Beaver Basin is considerable, but must be carefully utilized. Annual surface runoff is adequate, many small reservoir sites are available and ground water supplies are sufficient to serve moderate demands in most areas.

Eagle Creek Reservoir site has been investigated in some detail and could provide an estimated 121,000 acre-feet of storage. The Grand River Reservoir could provide 2.2 million acre-feet of storage. The Grand River Reservoir, although outside of the Beaver subbasin, is in a strategic location and could contribute significantly to the control of flows on the Mahoning, Beaver and Ohio Rivers. Runoff from 900 square miles of the Beaver subbasin could be diverted in time of flood to be later released during low flow periods. Storage space would be available for five inches of runoff from the Mahoning Basin above Youngstown.

Five potential watershed projects covering 905 square miles have been identified. These include 32 detention structures.

Ground water in large supplies is available in the northern part of the subbasin. In the central and southern parts of the subbasin, aquifers yield intermediate supplies; but larger yields can be developed in a few small areas.

Scenic and wooded areas are available in the basin for outdoor recreation development and wildlife management, and if access to attractive locations is improved, recreational opportunity can be considerably enhanced.

The hydroelectric power potential of the Beaver subbasin has not been fully investigated; therefore, the amount of feasible hydroelectric power capacity is largely unknown. The identified undeveloped potential amounts to 100 mw.

4. Assessment of Resource Development Requirements. Principal water supply, water quality and flood problem areas, together with reservoirs and upstream watershed projects in the going program of development, and those identified as potential future projects, are shown on the subbasin map, figure BE-1. Summary data for projects in the going program are given in Appendix K, tables 15 through 21 and for identified potential projects in tables 24 through 28. The relationship of problem areas and projects in the going program is shown schematically in figure BE-2, and key data relating to problem areas are given in table BE-2. The schematic diagram was used for general orientation in analyzing problems and needs and establishing development requirements for streamflow control. An accounting of storage capacity for streamflow control is given in table BE-3. Results of the subbasin assessment to determine the magnitude and costs of resource development required to satisfy projected demands for water and related functions and services are summarized in table BE-4.

a. Requirements to be Furnished by Identified Resource Potential. Analysis of demands for water and related functions and services and of the means whereby these demands can be satisfied indicates that to solve water supply, water quality, and flood problems, development of additional storage capacity for streamflow control will be required; also, further local protection projects and channel improvements will be required in several locations, either singly or in combination with streamflow regulation, to better cope with flood problems.

Total storage capacity required to provide streamflow control is estimated to be 1,088,600 acre-feet in addition to the amount that will be made available upon completion of the going program. Of this amount, 481,400 acre-feet of reservoir capacity can be provided by the identified resource potential for control of floodflows; 405,000 acre-feet would be provided in the Grand River Reservoir, 33,000 acre-feet in Eagle Creek and 43,400 acre-feet distributed in 5 potential watershed projects. In addition, the location of two local protection projects, and 8 miles of channel improvements in watershed areas are identified. About 195,400 acre-feet of identified storage capacity can be provided to make water available to supplement streamflows during low flow periods. In addition to the foregoing specific amounts of storage capacity, 96,300 acre-feet of reservoir space is available for joint use. Storage capacity provisions for streamflow supplementation are limited to amounts which are beyond the capability of available surface flows and ground water sources to satisfy demands. The ground water potential is considered adequate to provide 198 million gallons per day toward satisfying 2020 water requirements.

Canalization of the Beaver and Mahoning Rivers would be part of a potential new waterway which would link the Ohio River and Lake Erie via Grand River Reservoir. Sixty-one miles of the 120-mile waterroute would be in the Beaver River subbasin with the rest extending into the Great Lakes drainage. The canal would satisfy a substantial demand for low-cost water

transport by industry in the valleys of the Mahoning and Beaver Rivers and would also meet the need for waterborne bulk commodity movements between Great Lakes ports and docks throughout the Ohio and Mississippi River systems. Realization of the project, however, will depend upon socio-economic issues not yet resolved.

The identified hydroelectric power potential of 100 megawatts installed capacity should be useable before 1980 to meet a portion of the growing Ohio Basin power requirements; inclusion of the power potential as an element of water resource development is based on judgment that the installation will prove to be desirable and economically feasible in comparison to alternative sources of power supply.

Total area in potentially feasible upstream watershed projects is about 579,000 acres. Of this amount, it is estimated that approximately 262,000 acres of cropland, pasture, and woodland will require treatment and management to enhance land productivity and serve other beneficial purposes. Retardation of runoff, control of erosion, and reduction of sediment transport to streams are important considerations.

The improvement of water quality in the streams and the availability of reservoirs, impoundments, and other developments would provide potential opportunities for over 23 million outdoor recreation days annually if access and facilities are made available. Of this amount, the Grand River Reservoir could provide opportunity for 20 million days of outdoor recreation annually.

b. Remaining Requirements. The 178,500 acre-feet of storage capacity required to supplement streamflows during low flow periods includes increments to serve localized areas not identified by specific location of need and provide stream regulation in several identified areas of need, but for which storage developments are not identified.

Storage capacity that can be made available in identified potential projects is sufficient to provide for subbasin flood control requirements and would also furnish a portion of the capacity required for flood stage reduction on the Ohio River. The 137,000 acre-feet for which additional development will be required is the remaining amount needed in the Beaver subbasin to assist in regulating the Ohio River Standard Project Flood to the maximum flood stage of record.

Additional outdoor water-based recreation facilities and fishing opportunity will be required to supply demands of the people in the Beaver subbasin. Also, new and improved facilities in the Beaver subbasin could help supply the outdoor recreational needs of the adjacent Pittsburgh Standard Metropolitan Statistical Area (SMSA) where resources are relatively lacking. The extent to which demand for outdoor recreation and fishing opportunity can be satisfied beyond that provided by identified developments has not been assessed. The surplus in hunting opportunities projected through 1980 could be utilized by people in adjacent subbasins.

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Remaining land treatment and management requirements are associated with the general land base outside potential watershed projects, with the exception that lands to be irrigated or drained may be located in or outside watershed projects. By the year 2020, approximately 475,000 acres of cropland, pasture, and woodland would be subject to treatment and management measures, some of the more common being contour farming of all types, controlled grassland farming, and improved forest management and utilization. These lands are accounted for in the general inventory of requirements but are not identified by specific location.

TABLE BE-1

BEAVER SUBBASIN
DEMAND FOR WATER AND RELATED FUNCTIONS AND SERVICES

	Unit	Base Year Amount	Projected Increase[1] 1980	2020
Water Withdrawal				
Municipal and Industrial[2]	Million Gallons Per Day	1,054.2	279.8	1,609.8
Electric Power Cooling	Million Gallons Per Day	467	0	190
Rural Communities	Million Gallons Per Day	24.8	0.4	8.2
Rural Domestic and Livestock	Million Gallons Per Day	3.55	0	1.03
Irrigation[3]	Million Gallons Per Day	0.3	0.1	0.9
Stream Assimilation of Organic Waste Effluent[4]	1,000 Population Equivalents	132.5	32.5	162.6
Flood Damage Prevention[5]	Million Dollars Annually	13.34	2.87	6.77
Waterway Freight Movement[6]	Million Ton-Miles Annually	0	600	3,500
Hydroelectric Power - Installed Capacity	Megawatts	0	(Assessed on a basin-wide basis)	
Outdoor Recreation	Million Recreation Days	1.8	16.4	46.2
Sport Fishing	Million Angler Days	0.91	0.16[7]	0.50[7]
Hunting	Million Hunter Days	0.51	0 [7]	0.05[7]
Commercial Fishing			(Assessed on a basin-wide basis)	
Land Treatment and Management	1,000 Acres	77	307	737
Drainage	1,000 Acres	29	97	131
Irrigation (Land Area)	1,000 Acres	0.5	0.4	2.0

NOTES: (1) Base year amounts plus projected increase equals gross demands.

(2) Mining industry water requirements not included; assessed on a basin-wide basis.

(3) Withdrawal shown is for average year; drought year may be 45 percent higher.

(4) Residual biochemical oxygen demand after 85 percent waste removal by treatment.

(5) The dollar amounts (1980 and 2020) are indices to the magnitude of the problem and the protection measures required to reduce the potential damaging effects of floods.

(6) An index to the canalization and waterway facilities required to accommodate the transport of waterborne freight.

(7) Net requirements.

TABLE BE-2

BEAVER SUBBASIN
PRINCIPAL CONSIDERATIONS IN DETERMINING STORAGE CAPACITY REQUIREMENTS FOR CONTROL OF STREAMFLOW

A. SUPPLEMENTAL STREAMFLOW REQUIRED AT KEY LOCATIONS TO CONTROL WATER QUALITY (CFS).

Problem Area[1]	Stream	Required Flow[2] 1980	Required Flow[2] 2020	Flow Provided by Going Program	Supplemental Flow Required 1980	Supplemental Flow Required 2020
Alliance, Ohio	Mahoning River	45	70	10	35	60
Warren-Youngstown, Ohio	Mahoning River	710	875	515	195	360
Butler, Pa	Connoquenessing Creek	52	70	10	42	60

B. WATER REQUIRED TO SATISFY DEMANDS FOR WITHDRAWAL AND USE (IN ADDITION TO THAT PROVIDED IN BASE YEAR) (MGD).

Item	1980	2020
1. Total withdrawal[3]	280	1,810
2. To be provided by groundwater	34	198
3. Total consumptive use	8	65

C. FLOOD DAMAGE AREAS.

Location	Residual Damages[4] (Millions Dollars)	
1. Upstream areas	0.70	
2. Major urban areas[1]	0.12	
New Castle, Pa, Neshannock Creek		
3. Other flood plain areas	1.36	
4. Total subbasin	2.18	Projected to 2.87 in 1980 and 6.77 in 2020.

NOTES: (1) See figure BE-1 for geographic location of principal problem areas and figure BE-2 for schematic relationship.

(2) Streamflow required to maintain a minimum of 4 parts per million of dissolved oxygen.

(3) Water required to satisfy municipal and industrial, electric power cooling, rural community, rural domestic and livestock, and irrigation demands.

(4) Estimated average annual damages with the 1965 flood control program completed (1965 constant dollars).

TABLE BE-3

BEAVER SUBBASIN
ACCOUNTING OF STORAGE CAPACITY FOR STREAMFLOW CONTROL
(IN ADDITION TO THAT PROVIDED IN THE GOING PROGRAM)

	Time Period 1980	2020
	Storage (1,000 Ac Ft)	
A. WATER QUALITY CONTROL.		
1. Storage required[1]	73.4	129.6
2. Storage provided in identified potential sites	62.1	113.4
3. Additional storage required	11.3	16.2
B. WATER WITHDRAWALS.		
1. Storage required	58.2	340.6
C. FLOOD CONTROL.		
1. Subbasin and Ohio River control requirement	465.4	618.4
2. Storage provided in identified potential sites	431.1	481.4
a. for solving localized problems	(26.1)	(43.4)
b. effective in controlling both subbasin and Ohio River flows	(405.0)	(438.0)
3. Additional storage required[2]	34.3	137.0
D. TOTAL STORAGE REQUIREMENT.		
1. Water quality control, water withdrawals, and flood control	597.0	1,088.6
2. Available in identified potential sites[3]	497.2	676.8
3. Joint use storage	65.5	96.3
4. Additional storage required[4]	34.3	315.5

NOTES: (1) Storage capacity required to provide supplemental flows at key urban locations and rural communities in upstream watershed areas.

(2) Remaining Beaver subbasin share of storage required to reduce the Ohio River Basin Standard Project Flood to the maximum flood stage of record.

(3) See figure BE-1.

(4) Terrain indicates storage sites are potentially available.

TABLE BE-4

BEAVER SUBBASIN
SUMMARY ASSESSMENT OF RESOURCE DEVELOPMENT REQUIREMENTS

Program Elements	Unit	Provided in Going Program	Additional Requirement[1] 1980 Amount	1980 Capital Cost ($1,000)	2020 (Accumulative) Amount	2020 (Accumulative) Capital Cost ($1,000)
PART 1. TO BE FURNISHED BY IDENTIFIED RESOURCE POTENTIAL WITHIN SUBBASIN.						
A. Streamflow Control and In-Stream Use						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	319.8	66.1	16,300	195.4	49,200
2. Control of Flood Flows						
a. reservoir and detention storage	1,000 Ac Ft	310.7	431.1	108,200	481.4	122,300
b. local protection projects	Miles	6.4	0	0	(2)	4,000
c. channel improvement	Miles	0	5	100	8	200
3. Navigable Waterway						
a. improvement to existing waterway	Miles of Channel	0	-	-	-	
b. new waterway	Miles of Channel	-	0	0	61	690,000
c. channel deepening to 12 feet	Miles of Channel	-	-	-	-	-
4. Hydroelectric Power - Installed Capacity	Megawatts	0	100	11,300	(Assessed on a Basin-wide Basis)	
B. Related Programs						
1. Outdoor Recreation[3][4]	Million Recreation Days	1.8	20.6	72,200	23.0	80,400
2. Watershed Project Land Treatment and Management[5]	1,000 Acres	77	157.0	3,900	261.8	6,600
	COSTS - PART 1			212,000		952,700
PART 2. REMAINING REQUIREMENTS.						
A. Streamflow Control and In-Stream Use[6]						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	-	0	0	178.5	45,500
2. Storage for Control of Flood Flows	1,000 Ac Ft	-	34.3	8,700	137.0	34,900
3. Hydroelectric Power				(Assessed on a Basin-wide Basis)		
B. Related Programs						
1. Outdoor Recreation[3][7]	Million Recreation Days	-	0.1	100	23.2	81,200
2. Fish and Wildlife						
a. sport fishing[3][7]	Million Angler Days	0.91	0.16	600	0.50	1,800
b. hunting[3][7]	Million Hunter Days	0.51	0	0	0.05	200
c. commercial fishery				(Assessed on a Basin-wide Basis)		
C. Land Treatment and Management						
1. Lands Outside Watershed Projects	1,000 Acres	-	149.5	3,700	475.3	11,900
2. Irrigation (Acres to be Irrigated)	1,000 Acres	0.5	.6	100	2.3	1,200
3. Drainage	1,000 Acres	29	98.6	17,600	125.3	22,300
	COSTS - PART 2			30,800		199,000
	TOTAL COSTS - (PARTS 1 AND 2)			242,800		1,151,700

NOTES:

(1) Requirement in addition to that provided by going development programs.

(2) Project dimensions not defined at this time.

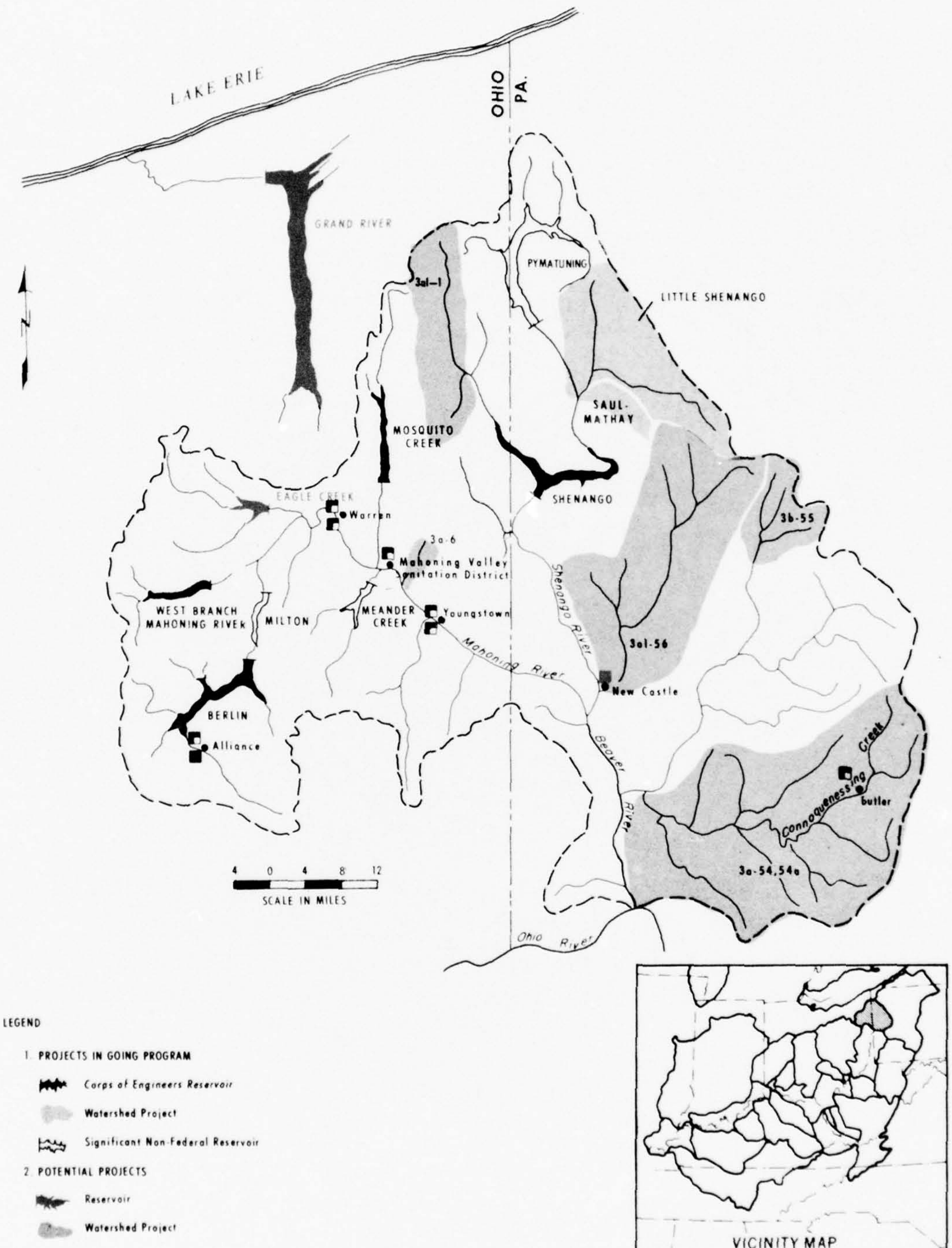
(3) Costs shown are for initial facilities and such measures as may be required to implement the program, and do not include water and related land cost. Base year 1960.

(4) The number of outdoor recreation days shown include some sport fishing and hunting which could not be separately accounted for in available days.

(5) Land area and costs shown are for total land treatment and management requirements in watershed projects and cover both water resource development related and other lands.

(6) Specific sites to provide storage capacity for streamflow control are not identified; however, favorable storage sites are potentially available.

(7) Because of population and resource distributions, remaining subbasin requirements for outdoor recreation, sport fishing and hunting not satisfied by water resource developments may require a trade off with adjacent subbasins or satisfied by other means.



LEGEND

1. PROJECTS IN GOING PROGRAM
   - Corps of Engineers Reservoir
   - Watershed Project
   - Significant Non-Federal Reservoir
2. POTENTIAL PROJECTS
   - Reservoir
   - Watershed Project
3. PROBLEM AREAS

	EXISTING	1980
Water Quality	■	■
Water Supply	■	■
Major Flood Damage	■	

OHIO RIVER BASIN COMPREHENSIVE SURVEY

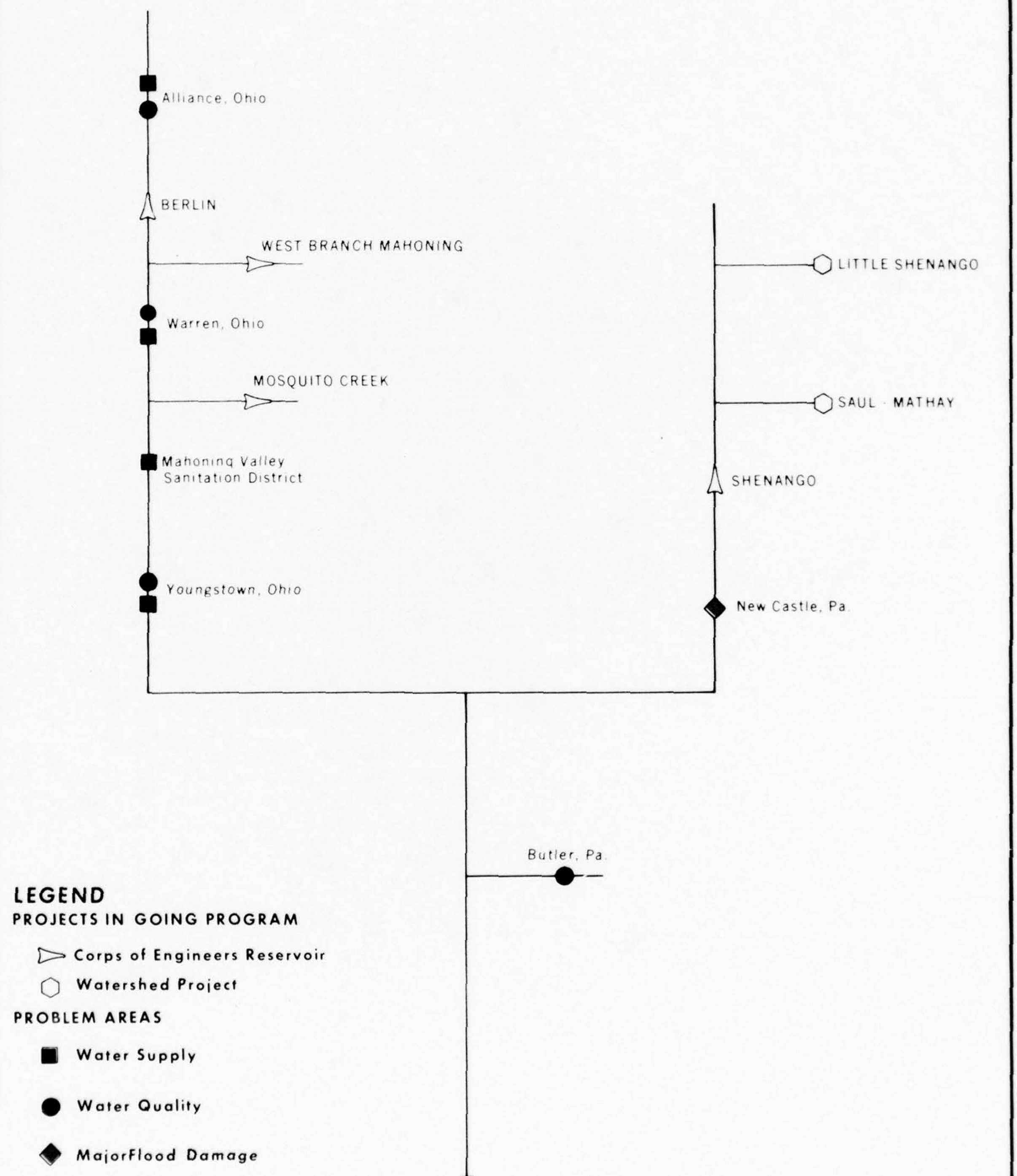
BEAVER SUBBASIN

PRINCIPAL
WATER SUPPLY, WATER QUALITY AND FLOOD PROBLEMS

RESERVOIRS AND WATERSHED PROJECTS
IN GOING PROGRAM, AND POTENTIALS

CORPS OF ENGINEERS
APPENDIX K

U.S. ARMY OHIO RIVER DIVISION
FIGURE BE-1



OHIO RIVER BASIN COMPREHENSIVE SURVEY

BEAVER SUBBASIN
ANALYSIS SCHEMATIC

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION
APPENDIX K FIGURE BE-2

MUSKINGUM

1. Planning Environment. - The Muskingum River subbasin, situated in the north-central portion of the Ohio Basin, is the largest drainage area in the State of Ohio. The subbasin contains 8,040 square miles, or five percent of the area included in the Ohio Basin study. The topography near the Ohio River is rolling to rugged with much of the land heavily forested. The remainder is relatively flat with the exception of land adjacent to the Muskingum and tributary river valleys.

The growing season is about average for the Ohio Basin. The subbasin has a history of recurring heavy winter and spring rains and summer thunderstorms with intense rainfall. Although runoff has been less than the average for the Ohio Basin, flooding occurs frequently. In contrast, extended droughts, although infrequent, have caused major crop losses and acute water shortages.

The Muskingum subbasin was settled in the late 1700's. Marietta, at the mouth of the Muskingum River, became the first settlement on the Ohio River. Frequent flooding at this city caused many discouraged settlers to move farther west. Some of the early immigrants settled in the highlands where rich soils and bountiful forests and wildlife made conditions ideal for a self-contained economy. Wagon trails across the northern portion of the subbasin were soon developed. Many small urban centers and rural communities stemmed from this early beginning. Industrial and commercial activity centered around an agricultural economy. Zanesville became the largest city in the subbasin.

The subbasin contains large commercial coal deposits, gas, oil, salt, and clay. About five percent of the Ohio Basin's total population reside in the Muskingum subbasin. They produce almost six percent of the Ohio Basin's industrial output. Projective economic studies indicate that the general economy of the Muskingum subbasin will continue to grow at a rate comparable to the overall Ohio Basin. Employment in the machinery and electrical equipment industries will continue to increase while agricultural employment will decline.

2. Demand for Water and Related Functions and Services. - The distribution of economic activity in the Muskingum Basin has resulted in widespread demands for water, flood protection, recreation, and other water related functions and services.

In general, water supplies are adequate in quantity, and if properly controlled, are sufficient to satisfy future demands; but the quality of surface waters and, in some cases ground water, is unfavorable for many uses. Acid drainage from active and abandoned mines in the southwestern and southern portions of the subbasin has degraded much of the streamflow. Chlorides as well as heat from industrial activity have also created pollution problems. Detailed studies will be required to define solutions to

mine drainage and chloride waste problems. Cooling towers for dissipating waste heat from thermal generating stations will undoubtedly be needed in lieu of streams for disposal of waste heat. The increased consumptive use must be made up by stream supplementation or provided from ground water.

Although there are many recreation areas in the Muskingum subbasin, further sources of opportunity must be made available if projected recreational desires are to be satisfied. Also, additional fishing and hunting opportunity will be required.

In order to reduce sediment loads in streams and impounded waters, further efforts are needed to reclaim strip mine areas and to control erosion on agricultural land by conservation, treatment and management measures.

a. Going Program Accomplishments. - Development and management programs by Federal, State and local interests have generally kept pace with most of the critical development needs. The Muskingum Conservancy District made early application of concepts leading to multiple-purpose use of water and related land resources. Legislative, research and reclamation efforts have been initiated to solve mine drainage problems and control erosion.

There are 15 existing Federal reservoirs in the subbasin. All but Dover, Bolivar, Mohicanville and Mohawk Reservoirs have recreation pools. The North Branch of the Kokosing River Reservoir is under construction. These provide a total of 1,604,000 acre-feet of storage capacity for control of floods and 4.4 thousand acre-feet of storage in joint use for other purposes. These 16 reservoirs control over 60 percent of the total subbasin area. Four major and two small local protection projects consisting of floodwalls, levees and channel improvements, further control damaging flood flows. The Chippewa Creek watershed project covers 188 square miles and contains nine detention structures and provisions for 33 miles of channel improvement. The project provides 6,294 acre-feet of flood detention storage and 2,767 acre-feet for other purposes. Salt Fork Reservoir, under construction by the State of Ohio, will provide water supply, some flood control and recreation. The foregoing developments would reduce average annual flood damages in downstream areas from $10.5 million to about $2.7 million and in upstream areas from $3.1 million to about $3.0 million.

Ground water within the subbasin has been tapped as the source for about 60 percent of the municipal and industrial water withdrawals. Canton, the largest single community using a ground water supply accounts for about 22 percent of the total municipal use. Also, many smaller communities and the rural areas in the basin are served primarily from ground water sources. There are seven non-Federal reservoirs for water supply; three of these provide recreational opportunity.

Commerce on the Muskingum River declined because of the inefficient outdated locks. This caused the Federal navigation project on the lower 93 miles to be discontinued in 1954. In 1958 the locks and dams and adjacent lands were transferred to the State of Ohio which has rehabilitated the system for recreational boating. Completion of the modern Belleville Locks and Dam on the Ohio River will allow the removal of Dam No. 1, and providing bridges are modified, Ohio River tows could operate in the lower reach of the Muskingum River. A water resources study on the Muskingum subbasin is presently underway by cooperating Federal and State agencies and is to be completed by 1970. This study will include consideration of a modern commercial navigation system.

Recreation facilities at reservoirs, along streams, at parks and forests and other recreation areas exist throughout the subbasin. Development and management programs have been put into effect to improve land cover and provide facilities for recreation, hunting and fishing throughout the subbasin. Even so, the provision of opportunity for outdoor recreation has not kept pace with demand. The Department of the Interior is considering a study for the feasibility of a national recreation area below Zanesville. In 1960, the subbasin provided for 2.8 million outdoor recreation days, 1.5 million angler days and 573,000 hunter days of activity.

b. Future Demand. - Base year amounts and projected increases in demand for water and related functions and services which will intensify demand for further use, development and management of water and related land resources are shown in table MU-1.

It should be noted that by 2020 water withdrawal demand will be over three times as great as in 1960. Stream quality problems are prevalent throughout most of the subbasin. In addition to organic waste many streams are polluted with chlorides, mine drainage and waste heat. Sufficient streamflow to provide waste assimilation capacity within acceptable standards of quality will be needed to absorb organic waste loads that are projected to increase more than threefold by 2020.

Although 58 percent of the total potential average annual damages from flood flows are prevented by existing flood control works, only three percent of the damages in upstream watersheds are prevented. About half of the dollar value of remaining potential damages in the subbasin are in upstream areas. Protection works and management programs will be needed to prevent projected 2020 potential flood damages, 3.3 times the average annual residual that existed with 1965 levels of flood plain development.

Additional electric power generation will be required to support industrial expansion and the general growth of the economy. By 2020, it is estimated that hydroelectric power plants could be efficiently utilized to provide about 10 percent of the total capacity requirements in the Ohio

Basin. Hydroelectric generation to be provided in the Muskingum subbasin will likely be limited.

Land area requiring treatment and proper management for efficient use is projected to increase to nearly 2.5 million acres by 2020. About 37,000 acres of strip-mined land are in need of rehabilitation. By 2020, the irrigated land area is projected to increase from 3,100 to 32,700 acres, whereas land that may be economically drained may reach 237,000 acres in addition to the 306,000 acres inventoried in 1960.

The demand for outdoor recreation is projected to increase six times by 2020. This demand, in conjunction with increased hunting and fishing needs, will require full utilization of all water and land resource potentials.

3. Resource Availability. - The water resource development potential of the Muskingum Basin is substantial. However, remaining reservoir sites are generally small. Annual surface runoff is sufficient to serve projected needs, if controlled, and ground water supplies are good in most areas.

Ten potential reservoirs with an estimated 287,200 acre-feet capacity have been investigated in some detail and are currently considered feasible. Only three of the reservoirs are over 20,000 acre-feet capacity. There are 24 potential upstream watershed projects where potential storage totaling 1.2 million acre-feet can be developed.

Ground water is abundant in the northern and western sections of the basin in both bedrock and glacial drift aquifers. In the remainder of the basin, large supplies are available only from sand and gravel aquifers in the valleys of the larger tributary streams.

No hydroelectric power sites have been identified in the Muskingum subbasin; however, the hydroelectric power potential has not been fully investigated. Therefore, the amount of hydroelectric power capacity that might become feasible in the future is unknown.

There are many scenic and wooded areas available in the basin for outdoor recreation development and wildlife management. If attractive facilities are provided, recreational opportunity can be considerably enhanced.

4. Assessment of Resource Development Requirements. - Principal water supply, water quality and flood problem areas, together with reservoirs and upstream watershed projects in the going program of development, and those identified as potential future projects, are shown on the subbasin map, figure MU-1. Summary data for projects in the going program are given in Appendix K, tables 15 through 21 and for identified potential

projects in tables 24 through 28. The relationship of problem areas and projects in the going program is shown schematically in figure MU-2, and key data relating to problem areas are given in table MU-2. The schematic diagram was used for general orientation in analyzing problems and needs and establishing development requirements for streamflow control. Table MU-3 contains an accounting of storage capacity for streamflow control. Results of the subbasin assessment to determine the magnitude and costs of resource development required to satisfy projected demands for water and related functions and services are summarized in table MU-4.

a. Requirements to be Furnished by Identified Resource Potential. - Analysis of future requirements in the Muskingum subbasin indicates the solution to water supply; water quality and flood problems will require additional facilities for control of streamflows and possible reallocation of storage in existing reservoirs. Storage space required by 2020 to provide streamflow control is estimated to be 1,738,800 acre-feet in addition to the amount that will be available upon completion of the going program. About 624,000 acre-feet, including 156,600 acre-feet associated with watershed projects, will be required for control of flood flows and about 1,115,000 acre-feet to provide for low flow requirements.

Storage capacity of 356,000 acre-feet can be provided in ten identified reservoirs and several potential upstream watershed project impoundments for control of flood flows. In addition, one major local protection project, and 850 miles of channel improvements dispersed in the potential upstream watershed projects would provide additional flood protection. Aggressive prosecution of alternative means for alleviating the damaging effects of floods, such as flood plain zoning, flood proofing, improved flood forecasting and flood plain evacuation procedures, etc., should be made an integral part of flood damage prevention efforts.

Twenty-three areas which will require additional water to meet withdrawal demands by 2020 have been identified. There are 14 areas requiring flow supplementation for water quality improvement by 2020. A higher degree of waste treatment than normal will probably be required to eliminate problems in some areas. The needs in the major problem areas can be met by existing reservoirs aided by new strategically located reservoirs and some joint use storage. Identified potential reservoirs can provide 200,700 acre-feet of storage capacity for low flow supplementation of which about 143,000 acre-feet is in potential upstream watershed projects. Storage requirements for supplementation of flows during low flow periods were established giving consideration to normal streamflow and ground water availability. Storage requirements were limited to needs beyond the availability of those alternative sources of supply. Over 110 million gallons per day, in addition to amounts presently taken from ground water, would come from wells by 2020.

Total area in potential feasible upstream watershed projects is about 2.6 million acres. Of this amount, it is estimated that approximately a million and a quarter acres of cropland, pasture, and woodland will require treatment and management to enhance land productivity and serve other beneficial purposes. Retardation of runoff, control of erosion, and reduction of sediment transport to streams are important considerations.

The availability of clean streams, reservoirs, impoundments, and other identified resource developments would provide potential opportunities for over 12.9 million outdoor recreation days annually if access and facilities are made available. Of this amount, opportunity for 5.8 million annual recreation days would be made available in potential upstream watershed projects.

b. <u>Remaining Requirements</u>. - The remaining 842,900 acre-feet of storage capacity required to supplement streamflows during low flow periods includes an increment of water required in localized areas not identified by specific location of need and an amount to provide stream regulation in several identified areas of need, but for which storage developments are not identified. Reservoir storage potential for quality control is physically limited. It has been provided in the assessment, but may prove more costly than advanced waste treatment. Reallocation of storage may be a logical solution and should be explored in detailed studies.

Storage capacity that can be made available in identified potential projects is sufficient to provide for subbasin flood control requirements and would also furnish a portion of the capacity required for flood stage reduction on the Ohio River. The 268,000 acre-feet for which additional development will be required is the remaining amount needed in the Muskingum subbasin to assist in regulating the Ohio River Standard Project Flood.

The extent to which demand for outdoor recreational opportunity can be satisfied beyond that provided by identified developments has not been assessed. A portion of the remaining requirement can be met in conjunction with other needed water resource developments in the subbasin. The rest will likely have to be provided by single-purpose recreation lakes, State and local parks, and private developments. For a period of time, opportunities within the Hocking subbasin could partially alleviate the shortage of opportunity in the Muskingum subbasin.

Remaining land treatment and management requirements are associated with the general land base outside watershed projects, with the exception that lands to be irrigated or drained may be located in or outside watershed projects. By the year 2020, it is estimated that approximately 1.1 million acres of cropland, pasture, and woodland will be in need of treatment and management measures, some of the more common being contour farming of all types, controlled grassland farming, and improved forest management and utilization. These lands are accounted for in the general inventory of requirements but are not identified by specific location.

TABLE MU-1

MUSKINGUM SUBBASIN
DEMAND FOR WATER AND RELATED FUNCTIONS AND SERVICES

	Unit	Base Year Amount	Projected Increase(1) 1980	Projected Increase(1) 2020
Water Withdrawal				
Municipal and Industrial(2)	Million Gallons Per Day	157.8	110.7	454.2
Electric Power Cooling	Million Gallons Per Day	1,328	252	2,572
Rural Communities	Million Gallons Per Day	42.1	0.7	15.9
Rural Domestic and Livestock	Million Gallons Per Day	10.81	0.40	7.21
Irrigation(3)	Million Gallons Per Day	1.8	1.3	15.5
Stream Assimilation of Organic Waste Effluent(4)	1,000 Population Equivalents	149.3	94.6	376.6
Flood Damage Prevention(5)	Million Dollars Annually	7.85	7.39	19.15
Waterway Freight Movement(6)	Million Ton-Miles Annually	0	0	0
Hydroelectric Power - Installed Capacity	Megawatts	0	(Assessed on a basin-wide basis)	
Outdoor Recreation	Million Recreation Days	2.8	26.8	75.3
Sport Fishing	Million Angler Days	1.50	0.02(7)	0.55(7)
Hunting	Million Hunter Days	0.57	0.08(7)	0.19(7)
Commercial Fishing			(Assessed on a basin-wide basis)	
Land Treatment and Management	1,000 Acres	120	925	2,358
Drainage	1,000 Acres	306	191	237
Irrigation (Land Area)	1,000 Acres	3.1	3.3	32.7

NOTES: (1) Base year amounts plus projected increase equals gross demands.

(2) Mining industry water requirements not included; assessed on a basin-wide basis.

(3) Withdrawal shown is for average year; drought year may be 45 percent higher.

(4) Residual biochemical oxygen demand after 85 percent waste removal by treatment.

(5) The dollar amounts (1980 and 2020) are indices to the magnitude of the problem and the protection measures required to reduce the potential damaging effects of floods.

(6) An index to the canalization and waterway facilities required to accommodate the transport of waterborne freight.

(7) Net requirements.

TABLE MU-2

MUSKINGUM SUBBASIN
PRINCIPAL CONSIDERATIONS IN DETERMINING STORAGE CAPACITY REQUIREMENTS
FOR CONTROL OF STREAMFLOW

A. SUPPLEMENTAL STREAMFLOW REQUIRED AT KEY LOCATIONS TO CONTROL WATER QUALITY (CFS).

Problem Area(1)	Stream	Required Flow(2)		Flow Provided by Going Program	Supplemental Flow Required	
		1980	2020		1980	2020
Barberton	Tuscarawas River	55	120	20	35	100
Massillon	Tuscarawas River	75	125	68	7	57
Orrville	Little Chippewa Creek	18	30	0	18	30
Rittman	River Styx	11	20	0	11	20
Wadsworth	River Styx	11	20	0	11	20
Canton	Nimishillen Creek	210	320	23	187	297
Dennison-Uhrichsville	Stillwater Creek	18	30	0	18	30
Shelby	Black Fork, Mohican River	18	30	0	18	30
Ashland	Jerome Fork	40	70	2	38	68
Mansfield	Rocky Fork, Black Fork, Mohican River	85	150	10	75	140
Mount Vernon	Kokosing River	26	45	18	8	27
Wooster	Killbuck Creek	40	70	8	32	62
Newark	Licking River	70	120	40	30	80
Cambridge	Wills Creek	22	40	0	22	40

B. WATER REQUIRED TO SATISFY DEMANDS FOR WITHDRAWAL AND USE (IN ADDITION TO THAT PROVIDED IN BASE YEAR) (MGD).

Item	1980	2020
1. Total withdrawal(3)	365	3,065
2. To be provided by groundwater	30	110
3. Total consumptive use	16	118

C. FLOOD DAMAGE AREAS.

Location	Residual Damages(4) (Millions Dollars)	
1. Upstream areas	2.99	
2. Major urban areas(1)	0.18	
Mansfield, Ohio, Rocky Fork Zanesville, Ohio, Muskingum River		
3. Other flood plain areas	2.57	
4. Total subbasin	5.74	Projected to 7.39 in 1980 and 19.15 in 2020.

NOTES: (1) See figure MU-1 for geographic location of principal problem areas and figure MU-2 for schematic relationship.

(2) Streamflow required to maintain a minimum of 4 parts per million of dissolved oxygen.

(3) Water required to satisfy municipal and industrial, electric power cooling, rural community, rural domestic and livestock, and irrigation demands.

(4) Estimated average annual damages with the 1965 flood control program completed (1965 constant dollars).

TABLE MU-3

MUSKINGUM SUBBASIN
ACCOUNTING OF STORAGE CAPACITY FOR STREAMFLOW CONTROL
(IN ADDITION TO THAT PROVIDED IN THE GOING PROGRAM)

	Time Period 1980	2020
	Storage (1,000 Ac Ft)	
A. WATER QUALITY CONTROL.		
1. Storage required(1)	326.4	592.3
2. Storage provided in identified potential sites	54.3	74.3
3. Additional storage required	272.1	518.0
B. WATER WITHDRAWALS.		
1. Storage required	116.0	522.5
C. FLOOD CONTROL.		
1. Subbasin and Ohio River control requirement	160.3	624.0
2. Storage provided in identified potential sites	93.3	356.0
a. for solving localized problems	(65.3)	(156.6)
b. effective in controlling both subbasin and Ohio River flows	(28.0)	(199.4)
3. Additional storage required(2)	67.0	268.0
D. TOTAL STORAGE REQUIREMENT.		
1. Water quality control, water withdrawals, and flood control	602.7	1,738.8
2. Available in identified potential sites(3)	260.4	556.7
3. Joint use storage	18.7	71.2
4. Additional storage required(4)	323.6	1,110.9

NOTES: (1) Storage capacity required to provide supplemental flows at key urban locations and rural communities in upstream watershed areas.

(2) Remaining Muskingum subbasin share of storage required to reduce the Ohio River Basin Standard Project Flood to the maximum flood stage of record.

(3) See figure MU-1.

(4) Terrain indicates storage sites are potentially available.

TABLE MU-4

MUSKINGUM SUBBASIN
SUMMARY ASSESSMENT OF RESOURCE DEVELOPMENT REQUIREMENTS

Program Elements	Unit	Provided in Going Program	Additional Requirement[1] 1980 Amount	1980 Capital Cost ($1,000)	2020 (Accumulative) Amount	2020 (Accumulative) Capital Cost ($1,000)
PART 1. TO BE FURNISHED BY IDENTIFIED RESOURCE POTENTIAL WITHIN SUBBASIN.						
A. Streamflow Control and In-Stream Use						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	4.4	167.1	27,000	200.7	32,600
2. Control of Flood Flows						
a. reservoir and detention storage	1,000 Ac Ft	1,610.0	93.3	30,500	356.0	90,500
b. local protection projects	Miles	15.6	0	0	(2)	8,100
c. channel improvement	Miles	33	354	7,100	850	17,100
3. Navigable Waterway						
a. improvement to existing waterway	Miles of Channel	91	0	0	0	0
b. new waterway	Miles of Channel	-	-	-	-	-
c. channel deepening to 12 feet	Miles of Channel	-	-	-	-	-
4. Hydroelectric Power - Installed Capacity	Megawatts	0	0	0	(Assessed on a Basin-wide Basis)	
B. Related Programs						
1. Outdoor Recreation[3][4]	Million Recreation Days	2.8	2.8	10,000	12.9	44,600
2. Watershed Project Land Treatment and Management[5]	1,000 Acres	120	524.5	13,100	1,257.7	31,400
	COSTS - PART 1			87,700		224,300
PART 2. REMAINING REQUIREMENTS.						
A. Streamflow Control and In-Stream Use[6]						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	-	256.6	65,400	842.9	214,900
2. Storage for Control of Flood Flows	1,000 Ac Ft	-	67.0	17,100	268.0	68,300
3. Hydroelectric Power				(Assessed on a Basin-wide Basis)		
B. Related Programs						
1. *Outdoor Recreation*[3][7]	*Million Recreation Days*	-	*24.0*	83,600	62.4	217,700
2. Fish and Wildlife						
a. sport fishing[3][7]	Million Angler Days	1.50	0.02	100	0.55	1,900
b. hunting[3][7]	Million Hunter Days	0.57	0.08	300	0.19	700
c. commercial fishery				(Assessed on a Basin-wide Basis)		
C. Land Treatment and Management						
1. Lands Outside Watershed Projects	1,000 Acres	-	400.8	10,000	1,100.3	27,500
2. Irrigation (Acres to be Irrigated)	1,000 Acres	3.1	3.4	300	32.8	3,000
3. Drainage	1,000 Acres	306	168.8	26,200	206.9	32,100
	COSTS - PART 2			203,000		566,100
	TOTAL COSTS - (PARTS 1 AND 2)			290,700		790,400

NOTES: (1) Requirement in addition to that provided by going development programs.

(2) Project dimensions not defined at this time.

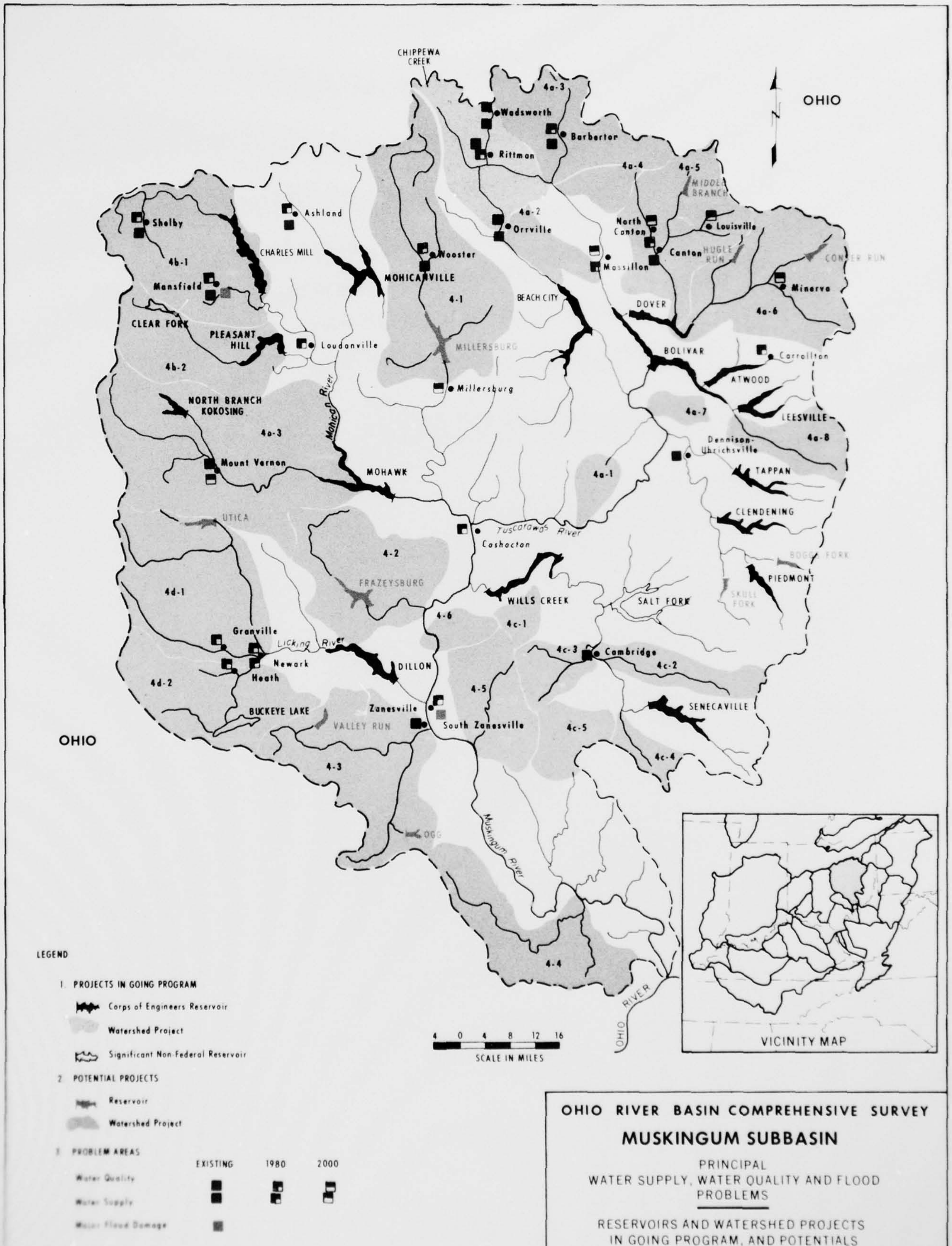
(3) Costs shown are for initial facilities and such measures as may be required to implement the program, and do not include water and related land cost. Base year 1960.

(4) The number of outdoor recreation days shown include some sport fishing and hunting which could not be separately accounted for in available data.

(5) Land area and costs shown are for total land treatment and management requirements in watershed projects and cover both water resource development related and other lands.

(6) Specific sites to provide storage capacity for streamflow control are not identified; however, favorable storage sites are potentially available.

(7) Because of population and resource distributions, remaining subbasin requirements for outdoor recreation, sport fishing and hunting not satisfied by water resource developments may require a trade off with adjacent subbasins or satisfied by other means.



OHIO RIVER BASIN COMPREHENSIVE SURVEY

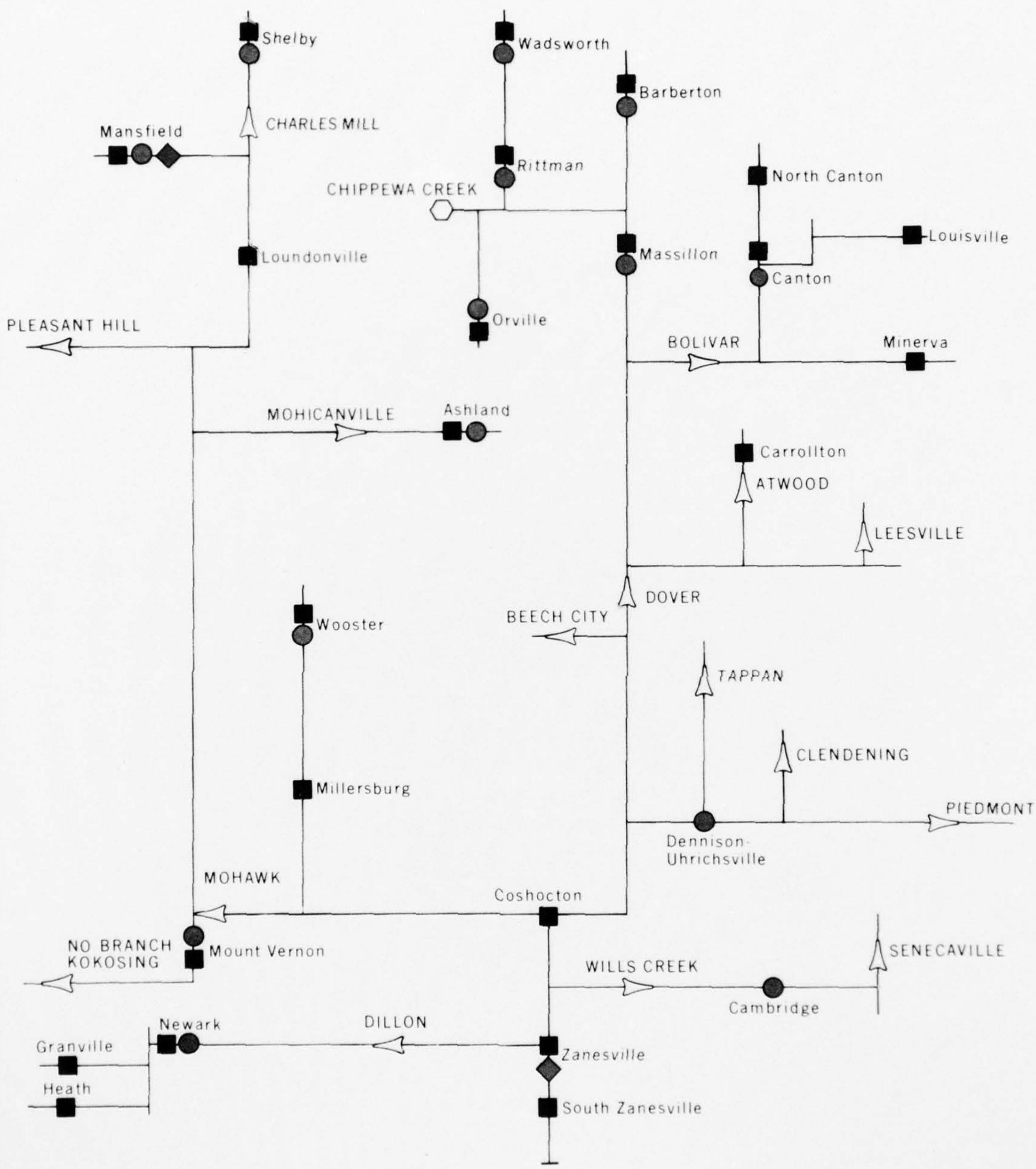
MUSKINGUM SUBBASIN

PRINCIPAL
WATER SUPPLY, WATER QUALITY AND FLOOD PROBLEMS

RESERVOIRS AND WATERSHED PROJECTS IN GOING PROGRAM, AND POTENTIALS

CORPS OF ENGINEERS
APPENDIX K

U.S. ARMY OHIO RIVER DIVISION
FIGURE MU-1



LEGEND

PROJECTS IN GOING PROGRAM

Corps of Engineers Reservoir

Upstream Watershed Project

PROBLEM AREAS

Water Supply

Water Quality

Major Flood Damage

Note: Subbasin is Located in Ohio

OHIO RIVER BASIN COMPREHENSIVE SURVEY

MUSKINGUM SUBBASIN
ANALYSIS SCHEMATIC

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION
APPENDIX K FIGURE MU-2

KANAWHA AND LITTLE KANAWHA

1. Planning Environment. The Kanawha and Little Kanawha subbasins, situated in the southeasterly portion of the Ohio Basin, lie mostly within the Appalachian Plateau. The topography is rolling to rugged with much of the land heavily forested. The highest altitude, 5,700 feet, is in the Blue Ridge Mountains. The Kanawha subbasin lies principally in West Virginia with about 30 percent of the headwaters in western Virginia and North Carolina. The Kanawha subbasin contains 12,200 square miles and the Little Kanawha, lying entirely in the State of West Virginia, contains 2,320 square miles. Together, they encompass nearly nine percent of the area included in the Ohio Basin study.

The two subbasins have a history of recurring heavy snowfall, widespread heavy rains, occasionally from hurricane-influenced storms, and local intense rainfall during summer thunderstorms. Extended droughts, although infrequent, have caused crop losses and acute water supply shortages. Runoff has been greater than the Ohio Basin average and contributes materially to flooding in the Ohio River. About seven percent of the flood damages within the Ohio Basin are accounted for in the Kanawha subbasin.

The Kanawha subbasin was known to settlers of Virginia as early as 1634. A portage of only a few miles linked the waters of the James River in Virginia with those of the Great Kanawha. When first settled, the Kanawha subbasin was covered with extensive stands of valuable timber and possessed large reserves of coal, salt, oil and natural gas. This combination of resources led to the development of important mining and chemical industries. Today the banks of the navigable reach of the lower Kanawha near Charleston, West Virginia are lined with manufacturing and industrial plants producing a varied number of products.

The Kanawha-Little Kanawha subbasins contain 4.7 percent of the population and four percent of the labor force in the Ohio Basin study area, and produce 3.6 percent of the industrial output. Projective economic studies of the Ohio Basin indicate that the Kanawha and Little Kanawha subbasins will maintain a relatively constant position in relation to the total Ohio Basin economy. Although coal production is expected to increase and present mining employment double, only four percent of the labor force will be engaged in mining by 1980. Largest employment is expected to be in the construction industry and in chemical, lumber and furniture, and apparal manufacturing.

2. Demand for Water and Related Functions and Services. The concentration of economic activity in the downstream portion of the Kanawha River has resulted in large demands for water, flood control, recreation, navigation and other water related functions and services, and the aggrevation of problems associated with municipal and industrial waste and other stream pollution.

KANAWHA AND LITTLE KANAWHA

Improvement of water quality is a major concern throughout the Kanawha subbasin. The quality of surface waters, and in some cases ground water, is unfavorable for many uses. Tastes and odors render some of the waters unfit for domestic use. Dissolved oxygen often is completely exhausted in some reaches of the Kanawha River for several weeks each year. Drainage and sediments from active and abandoned mines further degrade the streamflow. Approximately 14 percent of the municipal and industrial water withdrawal requirement in the Ohio River Basin with a corresponding requirement for assimilation of waste effluent is concentrated in the highly industrialized lower portion of the Kanawha subbasin.

Flooding is still a problem at several locations. Average annual potential damages are high in the Charleston-St. Albans-Nitro area. There are no major flood damage centers in the Little Kanawha subbasin but protection in upstream areas and additional measures for erosion control are needed.

The people of the Charleston metropolitan area are in need of additional outdoor water-based recreation facilities. If predicted future recreational desires are to be satisfied, further sources of opportunity will be required. Realization of the substantial potential for recreation development within the subbasins will necessitate the provision of ready access to the resource areas and the construction of adequate facilities.

The mining industry with large coal reserves in the basin together with the chemical industry depend on the availability of low-cost transportation for the transport of bulk commodities. Manufacturing output in the area along the Kanawha River Valley is projected to grow 110 percent during the period 1960 to 1980 and growth in mining output about 76 percent. This development would increase river traffic nearly 2.5 times. Early modernization of the entire navigable reach will be essential to provide waterway capacity to support expansion of the chemical industry in the valley and the development of the vast local coal reserves.

a. Going Program Accomplishment. Efforts have been made by Federal, state and local interests to solve mine drainage problems, control chemical and organic waste pollution of streams, prevent flooding, improve the navigable waterway and provide for outdoor recreation, sport fishing and hunting demands. Programs for land management, and fish and wildlife preservation have been in effect for some time.

As of July 1965, two Federal reservoir projects were complete and in operation in the Kanawha subbasin and one was under construction. These reservoirs with 1,252,000 acre-feet of flood storage space and 229,000 acre-feet of joint use space, control the run-off from about 40

percent of the subbasin drainage area. In addition, three major local protection projects were complete and five upstream watershed projects with provisions for flood water detention and channel improvements had been authorized. Two small local protection projects were complete and two under construction. In the Little Kanawha subbasins, one small local protection project was complete and two upstream watershed projects had been authorized. The foregoing projects would prevent 10.7 million dollars average annual damages under 1965 conditions of flood plain development.

Flowing streams within the two subbasins have been tapped as the principal source for electric power cooling water and major municipal and industrial water withdrawals. Existing impoundments, in most cases, have been associated with the provision of small public sources of water supply. About 22 percent of municipal and industrial water requirements and nearly all of rural area withdrawals are taken from ground water sources.

Three locks and dams on the Kanawha River in combination with the Gallipolis dam-lock unit on the Ohio River provide 90.6 miles of slack water for transport of waterborne freight. These units, in conjunction with channel dredging, assure a minimum 9-foot depth in the canalized reach of river. The practical physical capacity of the Kanawha waterway is about 900 million ton-miles of transport annually.

There are seven privately-owned hydroelectric power plants with a total installed capacity of 250.7 megawatts; all are in the Kanawha subbasin. These plants represented nearly one fourth of the total hydroelectric power installed in the Ohio River Basin.

Recreational facilities have been provided at reservoirs, along natural streams and in state and national forests by Federal and non-Federal interests. More than 40 state parks, forests and recreation areas exist in the subbasins. In 1960, water related recreational activity amounted to 4.7 million recreation days and 2.2 million hunter days and 870 thousand angler days of hunting and fishing.

b. Future Demand. Base year amounts and projected increases in demand for water and related functions and services which will intensify demand for future use, development and management of water and related land resources are shown in table KA-1.

Water withdrawal demands are projected to reach over 7 billion gallons per day by 2020, an increase of 5 billion gallons per day over withdrawals made in 1960. Municipal and industrial withdrawals will constitute 58 percent of the total in 2020 and water for electric power cooling about 41 percent. In 1960, the relative percentages were 67 and 30 respectively. Withdrawals for rural and farm use will about double, but remain only a small percentage of the total.

Sufficient streamflow to provide waste assimilation capacity within acceptable standards of quality will be required to absorb organic wasteloads that are projected to increase nearly 2.9 times the 1960 average by 2020. This is about 22 percent of the total organic waste effluent expected to be discharged to streams in the Ohio Basin study area.

About 60 percent of the potential average annual damages with 1965 level of flood plain development would be prevented by projects included in the going program for flood control. Residual average annual damages under these conditions would be about 8 million dollars, split about equally between upstream and downstream areas. By 2020, unless additional protection works and management actions are taken to prevent them, potential average annual damages are estimated to become nearly 3.5 times this amount with projected conditions of flood plain development. About two-thirds of the damages would be in downstream areas and one-third in upstream areas.

Modernization and deepening of the navigable waterway will be required to keep pace with demands for waterborne commerce generated by industrial expansion. Freight traffic is projected to reach 4.2 billion ton-miles by 2020 which will exceed the estimated capability of the existing navigation facilities on the Kanawha River by 4.6 times.

Additional electric power generation will be required to support industrial expansion and the general growth of the economy. By 2020, it is estimated that hydroelectric power plants could be efficiently utilized to provide about 10 percent of the total capacity requirements in the Ohio Basin. A part of this can be developed in the Kanawha subbasin at water control reservoirs and feasible pumped-storage sites to provide peaking capacity for use in conjunction with thermal or nuclear baseload plants.

Land area requiring treatment and proper management for efficient use is projected to total over 4.5 million acres by 2020. Sixty-six thousand acres of strip-mined land are in need of rehabilitation. Irrigated land area is relatively small. The projected increase by 2020 will only be 4,300 acres. Land that may be economically drained may double by 2020 reaching a total of 183,000 acres.

The demand for outdoor recreation is predicted to increase 4 times the 1960 use by 1980 and over tenfold by 2020. Sufficient opportunity exists to satisfy fishing demand through 1980; however, by 2020, additional opportunity will be required. A moderate increase in hunting demand is expected. These demands will require full use of water and lands affiliated with water resource development.

3. Resource Availability. The water resource development potential of the Kanawha Basin is one of the best in the Ohio Basin. Surface runoff

is high, reservoir sites are plentiful and ground water supplies are good in many areas. The natural quality of both surface and ground water is generally good. However, mine drainage and municipal and industrial pollution have degraded water quality in many areas.

The rugged topography and lack of major urban or industrial developments in many tributary valleys provide favorable opportunities to develop reservoirs for stream regulation. Twenty-four potential reservoirs with a total of about 4.5 million acre-feet of storage capacity have been investigated in some detail and are currently considered feasible. In addition 34 potential watershed projects have been identified, having 190 sites for developing a potential storage capacity of over a half million acre-feet. The reservoirs would control over 6,900 square miles of drainage area and the impoundments in upstream watershed areas over 1,000 square miles.

Availability of a considerable runoff and storage sites in the Kanawha subbasin makes it a key area for control of flow on the Ohio River. Also resource development will provide opportunities for the satisfaction of demands for outdoor recreation. Considering the ruggedness of scenic and wooded areas in the upper regions of the two subbasins, tourist recreation could rise in importance if access to attractive locations were improved.

In the Kanawha subbasin, ground water supplies for domestic needs are available in most areas. Larger yields suitable for industrial and public water supply are available in some areas. Yields of as much as 600 gallons per minute are obtained from individual wells in the central part of the basin. The unconsolidated alluvium along the Kanawha River Valley is a good potential source of ground water. As much as 150 gallons per minute have been obtained from vertical, screened wells. In the Little Kanawha subbasin, aquifers are relatively poor except in the headwaters and in the lower valley. Wells tapping sand and gravel aquifers yield as much as 100 gallons per minute.

The hydroelectric power potential of the Kanawha-Little Kanawha subbasins has not been fully investigated; therefore, the amount of feasible hydroelectric power capacity is largely unknown. However, the terrain indicates this might be substantial, particularly for high-head pumped-storage power projects, a few of which could utilize the reservoirs of projects for other purposes as upper or lower pools. The Appalachian Power Company has a license application pending before the Federal Power Commission for construction of the Blue Ridge project on the Upper New River which includes a pumped-storage hydroelectric power installation of 1600 MW (originally proposed for 900 MW) and a conventional plant of 200 MW (originally proposed for 80 MW). In addition, there are 13 identified locations in the Kanawha subbasin where conventional hydroelectric plants with a total of 1,200 MW are potentially feasible. Four of these

are on the Gauley River, one on the Meadow River and 8 on the New River, two of the latter being alternates to the Blue Ridge project. There are no identified sites in the Little Kanawha subbasin.

4. Assessment of Resource Development Requirements. Principal water supply, water quality and flood problem areas, together with reservoirs and upstream watershed projects in the going program of development, and those identified as potential future projects, are shown on the subbasin map, figure KA-1. Summary data for projects in the going program are given in Appendix K, tables 15 through 21 and for identified potential projects in tables 24 through 28. The relationship of problem areas and projects in the going program is shown schematically in figure KA-2, and key data relating to problem areas are given in table KA-2. The schematic diagram was used for general orientation in analyzing problems and needs and establishing development requirements for streamflow control. An accounting of storage capacity for streamflow control is given in table KA-3. Results of the subbasin assessment to determine the magnitude and costs of resource development required to satisfy projected demands for water and related functions and services are summarized in table KA-4.

a. Requirements to be Furnished by Identified Resource Potential. Analysis of demands for water and related functions and services and of the means whereby these demands can be satisfied indicates that to solve water supply, water quality, and flood problems, development of additional storage capacity for streamflow control will be required; also, further local protection projects and channel improvements will be required in several locations, either singly or in combination with streamflow regulation, to better cope with flood problems.

Total storage capacity required to provide streamflow control is estimated to be 9 million acre-feet in addition to the amount that will be made available upon completion of the going program. By 2020, nearly 7 million acre-feet of this amount will be required to provide sufficient streamflow at 15 locations with major water supply or water quality problems. About 3.1 million acre-feet of the requirement can be provided in identified potential reservoirs, including the joint use of 353,000 acre-feet of flood control space. Waste treatment in addition to flow supplementation, will undoubtedly be required to handle some of the complex industrial wastes in the lower reaches of the Kanawha and Little Kanawha Rivers. Storage capacity provisions for streamflow supplementation are limited to amounts required to satisfy demands beyond the capability of available surface flows and ground water sources. The ground water potential is considered adequate to provide 263 million gallons per day in addition to pumpage inventoried in 1960 toward satisfying 2020 water requirements.

KANAWHA AND LITTLE KANAWHA

About 1,765,000 acre-feet of reservoir capacity, including 229,000 acre-feet associated with upstream watershed projects, can be provided by the identified resource potential for control of floodflows. In addition, 35 miles of channel improvements in potential upstream watershed projects are identified. An aggressive flood plain management program will assist in maintaining the high percentage of damage reduction that will be afforded by proposed protection.

Traffic on the Kanawha River waterway has been growing steadily with the industrial expansion that has been taking place. The physical capacity of the existing navigation project for handling waterborne freight traffic will be reached in the near future. Therefore, a high priority should be established for the modernization of the Kanawha River system. This includes construction of a new lock system to coincide with about the time a modern dam-lock unit is completed near Gallipolis on the Ohio River, and the later deepening of the waterway to 12 feet concurrently with the provisions of a greater depth in the Ohio River channel.

The identified hydroelectric power potential of 2,100 megawatts installed capacity would be useable before 1980 to meet a portion of the growing Ohio Basin power requirements. Inclusion of the power potential as an element of water resource development is based on judgment that the installation will prove to be desirable and economically feasible in comparison to alternative sources of power supply.

Total area in potentially feasible upstream watershed projects is about 1.5 million acres. Of this amount, it is estimated that approximately 975,000 acres of cropland, pasture, and woodland in addition to that provided for in authorized projects will require treatment and management to enhance land productivity and serve other beneficial purposes. Over 70 percent is in woodland area. Retardation of runoff, control of erosion, and reduction of sediment transport to streams are important considerations.

The availability of streams with improved water quality, reservoirs, impoundments, and other potential developments would provide potential opportunities for nearly 20 million outdoor recreation days annually if access and facilities are made available.

b. Remaining Requirements. Nearly all of the additional 3.9 million acre-feet of storage capacity required to supplement streamflows during low flow periods will be utilized in the Charleston, West Virginia industrial area. The location of these storage developments are not identified. The balance of the storage capacity would be required to provide stream regulation in localized areas not identified by specific location of need.

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Storage capacity that can be made available in identified potential projects is sufficient to provide for subbasin flood control requirements and would also furnish a portion of the capacity required for flood stage reduction on the Ohio River. The 267,000 acre-feet for which additional development will be required is the remaining amount needed in the Kanawha-Little Kanawha subbasins to assist in regulating the Ohio River Standard Project Flood down to the maximum flood stage of record.

The extent to which demand for outdoor recreation, hunting, and fishing opportunity can be satisfied beyond that provided by identified developments has not been assessed. A portion of the remaining requirement can be met in conjunction with other needed water resource developments in the subbasin. The rest will likely have to be provided by single-purpose recreation lakes, State and local parks, and private developments, particularly for the Charleston metropolitan area.

Remaining land treatment and management requirements are associated with the general land base outside watershed projects, with the exception that lands to be irrigated or drained may be located in or outside watershed projects. By the year 2020, approximately 3.5 million acres of cropland, pasture, and woodland would be subject to treatment and management measures, some of the more common being contour farming of all types, controlled grassland farming, and improved forest management and utilization. These lands are accounted for in the general inventory of requirements but are not identified by specific location.

TABLE KA-1

KANAWHA, LITTLE KANAWHA SUBBASINS
DEMAND FOR WATER AND RELATED FUNCTIONS AND SERVICES

	Unit	Base Year Amount	Projected Increase[1] 1980	Projected Increase[1] 2020
Water Withdrawal				
Municipal and Industrial[2]	Million Gallons Per Day	1,540.6	584.8	2,732.4
Electric Power Cooling	Million Gallons Per Day	703	85	2,297
Rural Communities	Million Gallons Per Day	43.1	15.2	35.6
Rural Domestic and Livestock	Million Gallons Per Day	9.52	0	4.43
Irrigation[3]	Million Gallons Per Day	1.2	0.3	1.8
Stream Assimilation of Organic Waste Effluent[4]	1,000 Population Equivalents	1,031.4	372.7	1,995.8
Flood Damage Prevention[5]	Million Dollars Annually	10.71	9.72	27.52
Waterway Freight Movement[6]	Million Ton-Miles Annually	900	500	3,300
Hydroelectric Power - Installed Capacity	Megawatts	250.7	(Assessed on a basin-wide basis)	
Outdoor Recreation	Million Recreation Days	4.7	13.9	44.3
Sport Fishing	Million Angler Days	0.87	0 [7]	0.36[7]
Hunting	Million Hunter Days	2.16	0.25[7]	0.34[7]
Commercial Fishing			(Assessed on a basin-wide basis)	
Land Treatment and Management	1,000 Acres	97	1,572	4,518
Drainage	1,000 Acres	93	67	90
Irrigation (Land Area)	1,000 Acres	2.1	0.8	4.3

NOTES: (1) Base year amounts plus projected increase equals gross demands.

(2) Mining industry water requirements not included; assessed on a basin-wide basis.

(3) Withdrawal shown is for average year; drought year may be 45 percent higher.

(4) Residual biochemical oxygen demand after 85 percent waste removal by treatment.

(5) The dollar amounts (1980 and 2020) are indices to the magnitude of the problem and the protection measures required to reduce the potential damaging effects of floods.

(6) An index to the canalization and waterway facilities required to accommodate the transport of waterborne freight.

(7) Net requirements.

TABLE KA-2

KANAWHA, LITTLE KANAWHA SUBBASINS
PRINCIPAL CONSIDERATIONS IN DETERMINING STORAGE CAPACITY REQUIREMENTS
FOR CONTROL OF STREAMFLOW

A. SUPPLEMENTAL STREAMFLOW REQUIRED AT KEY LOCATIONS TO CONTROL WATER QUALITY (CFS).

Problem Area(1)	Stream	Required Flow(2) 1980	Required Flow(2) 2020	Flow Provided by Going Program	Supplemental Flow Required 1980	Supplemental Flow Required 2020
Kanawha Subbasin						
Charleston, W Va	Kanawha River	6,900	14,500	1,930	4,970	12,570
Beckley, W Va	Piney Creek	20	32	20	0	12
Durbin, W Va	East Fork Greenbrier River	15	15	1	14	14
Bluefield, Va	Bluestone River	15	33	1	14	32
Pulaski, Va	Peak Creek	15	21	6	9	15
Galax, Va	Chestnut Creek	22	26	16	6	10
West Jefferson, NC	Buffalo Creek	5	15	0	5	15
Little Kanawha Subbasin						
Mile Point 22 to Mouth	Little Kanawha River	300	300	8	292	292

B. WATER REQUIRED TO SATISFY DEMANDS FOR WITHDRAWAL AND USE (IN ADDITION TO THAT PROVIDED IN BASE YEAR) (MGD).

Item	1980	2020
1. Total withdrawal(3)	685	5,071
2. To be provided by groundwater	64	263
3. Total consumptive use	29	166

C. FLOOD DAMAGE AREAS.

Location	Residual Damages(4) (Millions Dollars)	
1. Upstream areas	3.82	
2. Major urban areas(1)	0.50	
Charleston, W Va, Kanawha River St. Albans-Nitro, W Va, Kanawha River Marlington, W Va, Greenbrier River		
3. Other flood plain areas	3.63	
4. Total subbasin	7.95	Projected to 9.72 in 1980 and 27.52 in 2020.

NOTES: (1) See figure KA-1 for geographic location of principal problem areas and figure KA-2 for schematic relationship.

(2) Streamflow required to maintain a minimum of 4 parts per million of dissolved oxygen.

(3) Water required to satisfy municipal and industrial, electric power cooling, rural community, rural domestic and livestock, and irrigation demands.

(4) Estimated average annual damages with the 1965 flood control program completed (1965 constant dollars).

TABLE KA-3

KANAWHA, LITTLE KANAWHA SUBBASINS
ACCOUNTING OF STORAGE CAPACITY FOR STREAMFLOW CONTROL
(IN ADDITION TO THAT PROVIDED IN THE GOING PROGRAM)

	Time Period 1980	2020
	Storage (1,000 Ac Ft)	
A. WATER QUALITY CONTROL.		
1. Storage required(1)	1,178.5	2,855.9
2. Storage provided in identified potential sites	888.9	2,764.9
3. Additional storage required	289.6	91.0
B. WATER WITHDRAWALS.		
1. Storage required	917.5	4,134.6
C. FLOOD CONTROL.		
1. Subbasin and Ohio River control requirement	603.3	2,032.1
2. Storage provided in identified potential sites	536.5	1,765.1
a. for solving localized problems	(118.3)	(229.2)
b. effective in controlling both subbasin and Ohio River flows	(418.2)	(1,535.9)
3. Additional storage required(2)	66.8	267.0
D. TOTAL STORAGE REQUIREMENT.		
1. Water quality control, water withdrawals, and flood control	2,699.3	9,022.6
2. Available in identified potential sites(3)	1,440.7	4,545.3
3. Joint use storage	107.3	353.0
4. Additional storage required(4)	1,151.3	4,124.3

NOTES: (1) Storage capacity required to provide supplemental flows at key urban locations and rural communities in upstream watershed areas.

(2) Remaining Kanawha, Little Kanawha subbasins share of storage required to reduce the Ohio River Basin Standard Project Flood to the maximum flood stage of record.

(3) See figure KA-1.

(4) Terrain indicates storage sites are potentially available.

TABLE KA-4

KANAWHA, LITTLE KANAWHA SUBBASINS
SUMMARY ASSESSMENT OF RESOURCE DEVELOPMENT REQUIREMENTS

Program Elements	Unit	Provided in Going Program	Additional Requirement[1] 1980 Amount	1980 Capital Cost ($1,000)	2020 (Accumulative) Amount	2020 (Accumulative) Capital Cost ($1,000)
PART 1. TO BE FURNISHED BY IDENTIFIED RESOURCE POTENTIAL WITHIN SUBBASIN.						
A. Streamflow Control and In-Stream Use						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	229.3	904.2	228,000	2,780.2	705,900
2. Control of Flood Flows						
a. reservoir and detention storage	1,000 Ac Ft	1,260.3	536.5	131,600	1,765.1	447,600
b. local protection projects	Miles	10.9	0	0	0	0
c. channel improvement	Miles	29	18	1,500	35	3,000
3. Navigable Waterway						
a. improvement to existing waterway	Miles of Channel	91	91	90,000	91	90,000
b. new waterway	Miles of Channel	-	-	-	-	-
c. channel deepening to 12 feet	Miles of Channel	-	0	0	91	20,000
4. Hydroelectric Power - Installed Capacity	Megawatts	250.7	2,100	236,300	(Assessed on a Basin-wide Basis)	
B. Related Programs						
1. Outdoor Recreation(2)(3)	Million Recreation Days	4.7	4.9	19,400	19.7	73,100
2. Watershed Project Land Treatment and Management(4)	1,000 Acres	97	502.5	12,600	974.2	24,400
	COSTS - PART 1			719,400		1,364,000
PART 2. REMAINING REQUIREMENTS.						
A. Streamflow Control and In-Stream Use(5)						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Act Ft	-	1,084.5	276,500	3,857.3	983,600
2. Storage for Control of Flood Flows	1,000 Ac Ft	-	66.8	17,000	267.0	68,100
3. Hydroelectric Power				(Assessed on a Basin-wide Basis)		
B. Related Programs						
1. Outdoor Recreation(2)(6)	Million Recreation Days	-	9.0	32,000	24.6	90,500
2. Fish and Wildlife						
a. sport fishing(2)(6)	Million Angler Days	0.87	0	0	0.36	1,300
b. hunting(2)(6)	Million Hunter Days	2.16	0.25	900	0.34	1,200
c. commercial fishery				(Assessed on a Basin-wide Basis)		
C. Land Treatment and Management						
1. Lands Outside Watershed Projects	1,000 Acres	-	1,070.5	26,800	3,543.6	88,600
2. Irrigation (Acres to be Irrigated)	1,000 Acres	2.1	.8	100	4.3	400
3. Drainage	1,000 Acres	93	34.4	5,000	39.7	5,800
	COSTS - PART 2			358,300		1,239,500
	TOTAL COSTS - (PARTS 1 AND 2)			1,077,700		2,603,500

NOTES: (1) Requirement in addition to that provided by going development programs.

(2) Costs shown are for initial facilities and such measures as may be required to implement the program, and do not include water and related land cost. Base Year 1960.

(3) The number of outdoor recreation days shown include some sport fishing and hunting which could not be separately accounted for in available data.

(4) Land area and costs shown are for total land treatment and management requirements in watershed projects and cover both water resource development related and other lands.

(5) Specific sites to provide storage capacity for streamflow control are not identified; however, favorable storage sites are potentially available.

(6) Because of population and resource distributions, remaining subbasin requirements for outdoor recreation, sport fishing and hunting not satisfied by water resource developments may require a trade off with adjacent subbasins or satisfied by other means.

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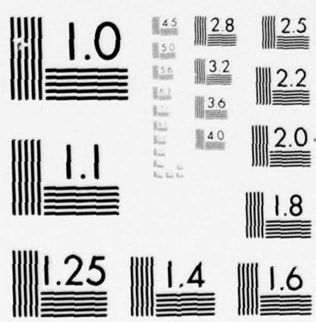

MICROCOPY RESOLUTION TEST CHART
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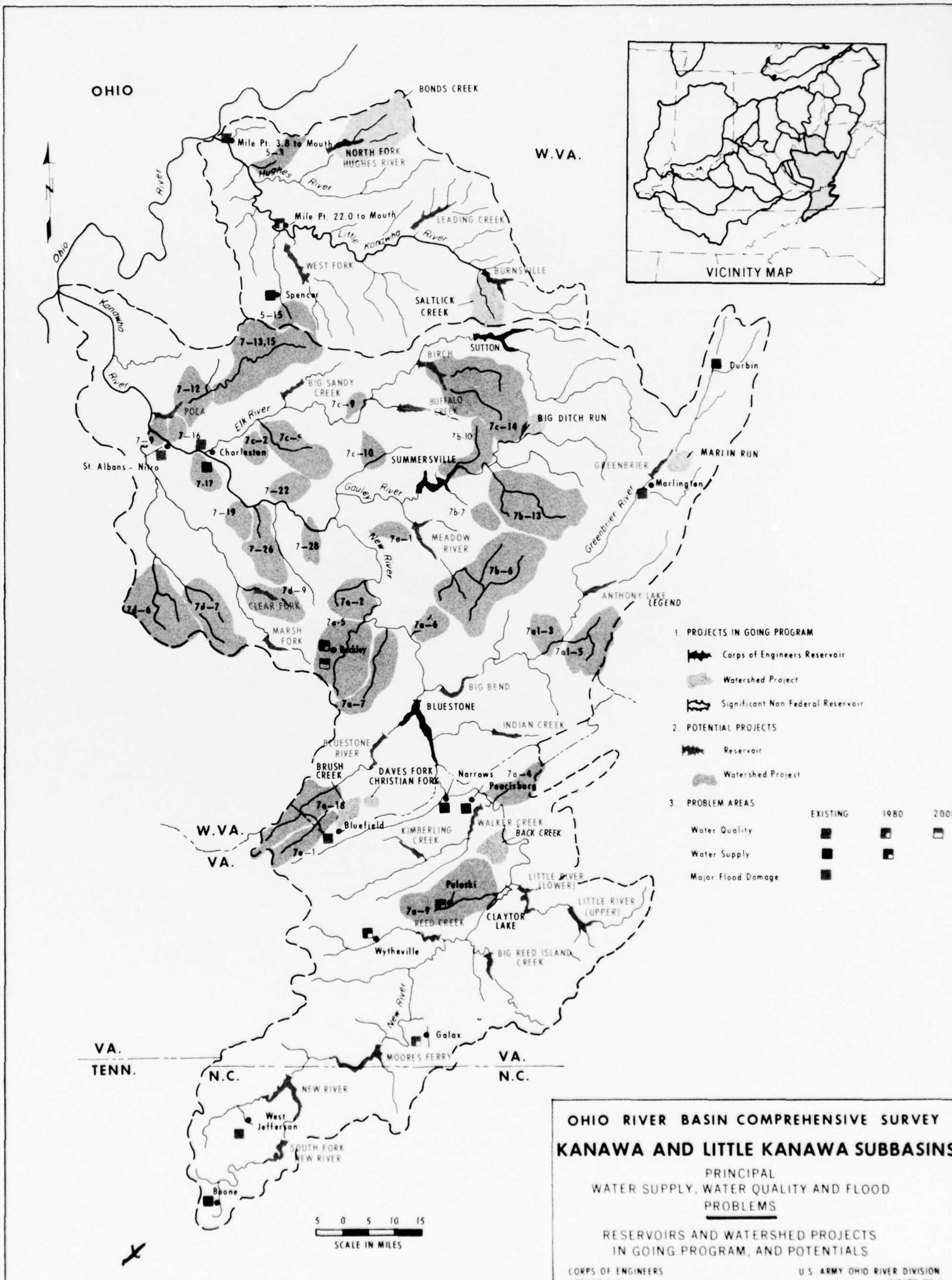


OHIO RIVER BASIN COMPREHENSIVE SURVEY

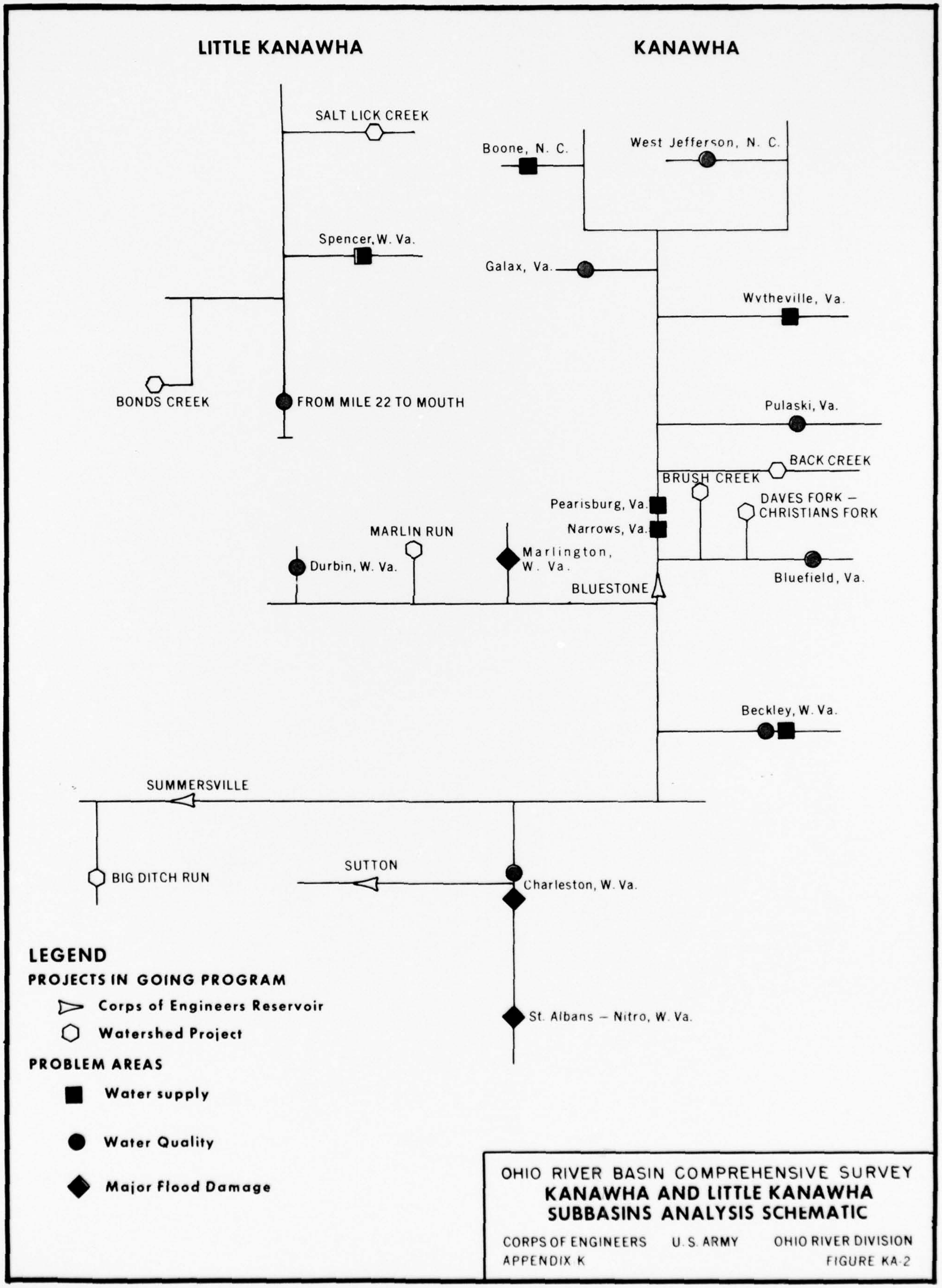
KANAWA AND LITTLE KANAWA SUBBASINS

PRINCIPAL
WATER SUPPLY, WATER QUALITY AND FLOOD
PROBLEMS

RESERVOIRS AND WATERSHED PROJECTS
IN GOING PROGRAM, AND POTENTIALS

CORPS OF ENGINEERS
APPENDIX K

U.S. ARMY OHIO RIVER DIVISION
FIGURE KA-1



OHIO RIVER BASIN COMPREHENSIVE SURVEY

KANAWHA AND LITTLE KANAWHA SUBBASINS ANALYSIS SCHEMATIC

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE KA-2

GUYANDOTTE, BIG SANDY AND LITTLE SANDY

1. Planning Environment. The Guyandotte, Big Sandy and Little Sandy River subbasins, situated in the south-central portion of the Ohio Basin, contain 6,652 square miles, or nearly four percent of the Ohio Basin study area. They include portions of southwestern West Virginia, western Virginia, and eastern Kentucky. The Big Sandy and one of its tributaries, the Tug Fork, form the entire length of the Kentucky-West Virginia boundary. The topography is rolling to rugged, with the maze of hills and valleys covered mostly by forests and pastureland. Many of the valleys are extremely narrow with the steep slopes rising abruptly from the streams. The steep hillsides generally leave little room for development in the river valleys except within the flood plains.

The subbasins have a history of recurring heavy rainfalls from winter storms and summer thunderstorms. Runoff has been greater than the average for the Ohio Basin, causing frequent floods within the subbasin and contributing materially to Ohio River flood problems. In contrast, extended droughts, although infrequent, have caused crop losses and acute water shortages.

The first settlers arrived in 1765, but there were no permanent communities until later in the century. Some of the early immigrants settled in isolated portions of the highlands where bountiful forests and wildlife provided a self-contained economy. Other migrants settled in the area adjacent to the confluences with the Ohio River to form urban communities of nominal size.

The subbasins contain large commercial coal deposits and a considerable portion of the economy is based on this resource. The Guyandotte and the Big and Little Sandy subbasins have about three percent of the Ohio River Basin population and about two percent of the labor force. Only 1.2 percent of the industrial output of the Ohio Basin is produced here. Projective economic studies indicate that the general economy of this area will continue to grow, but at a lesser rate than the overall Ohio Basin. Without additional economic stimulus, the area may experience a decline in population through outmigration.

2. Demand for Water and Related Functions and Services. In general, present water supplies are adequate in quantity, and if properly controlled, are sufficient to meet future demands. However, the surface waters are hard to moderately hard and many stream reaches contain fines from coal washing operations. Drainage from active and abandoned mines situated in the headwaters of the Guyandotte and Big Sandy subbasins have degraded much of the streamflow. Except in the lower slackwater reaches created by Greenup Dam there are no major organic waste problems. In most areas ground water is high in iron

content and removal is required for many uses. Management programs and physical works will be required for control of erosion and mine drainage to provide water quality improvement.

Flooding is a problem at several locations, particularly in upstream areas.

The mining industry with large coal reserves in the subbasins depends on low-cost transportation to supply the coal output to consumers. In consideration of the interrelation of the mining in the subbasins and industries in other nearby subbasins, further development of navigable channels will be required.

The people of the area are currently in need of additional outdoor water-based recreation facilities. If predicted future recreational desires are to be satisfied, further sources of opportunity will be required. Realization of the substantial potential for recreational development within the subbasins will require the provision of ready access to the resource areas and the construction of adequate facilities.

a. Going Program Accomplishments. Development and management programs by Federal, state and local interests have been established to cope with critical development needs. Legislative enactments and research and reclamation efforts have been initiated to solve mine drainage problems and sediment pollution of streams.

The flood control aspects of the Little Sandy River subbasin and consideration of potential upstream watershed projects and land treatment and management are included in the assessment of the Ohio River and minor tributaries. All other aspects are included with the Big Sandy and Guyandotte subbasin assessments.

Five Federal multiple-purpose reservoirs, when all are completed, will provide protection to downstream areas in the Big Sandy and Guyandotte subbasins. These provide a total of 521,000 acre-feet of storage for control of floods, 38,600 acre-feet of storage for low flow supplementation and 73,000 acre-feet in joint use for both purposes. These reservoirs will control about 21 percent of the total area in the two subbasins. Two major and 3 small local protection projects with floodwalls, levees, and channel improvements, will further control damaging flood flows. About 2.9 million dollars or about 75 percent of potential average annual damages would be prevented by these projects with 1965 level of flood plain development.

About 55 percent of water withdrawals by municipalities are taken from ground water sources. This varies from a low of 15 percent in the Guyandotte subbasin to a high of 58 percent in the Big Sandy.

Existing water supply impoundments are, in most cases, for the provision of small public sources of supply. Except for rural and farm needs, other water withdrawal demands are served primarily from surface water sources.

Irrigation and drainage developments are of minor significance, and no upstream watershed projects were authorized as of July 1965.

There are no hydroelectric generating plants in the basins.

With the exception of Dam No. 1 near the Ohio River, the Federal navigation project on the Big Sandy was abandoned in 1947. With the removal of Dam No. 1 in 1962, use of the lower reach in the slackwater area created by the Greenup navigation pool on the Ohio River has been increasing.

Recreation facilities at reservoirs and along natural streams have been provided by Federal and non-Federal interests. A portion of one National Forest and more than 17 state parks, forests and other recreation areas provide considerable opportunity for recreation. Development and management programs have been put into effect to improve land cover and provide facilities for recreation, hunting and fishing throughout the basin. In 1960, the basin provided 400,000 recreation days, one million angler days and nearly a million hunter days of outdoor recreation and fishing and hunting, respectively. Although hunting and fishing needs have been met, the provision of opportunity for outdoor recreation has not kept pace with demand.

b. Future Demand. Projected demands of the expanding economy which will intensify demand for further use, development and management of water and related land resources are shown in table GU-1.

It will be noted that 1960 water withdrawals will increase 2.7 times by 2020, increasing from about 254 million gallons per day to about 688 mgd.

The Guyandotte, Big Sandy and Little Sandy subbasins are unique in relation to the rest of the Ohio Basin study area in that no organic waste problems are projected for the future, at least in so far as any significant stream pollution is concerned except in the slackwater pool area in the lower tributary reaches. However, the timber resources are vast and the location of a single pulp mill on any one stream would greatly increase the stream pollution potential. This would significantly increase streamflow requirements for waste assimilation.

Estimated residual flood damages after completion of the going program for flood control would average about 3.9 million dollars

annually. Potential flood damages are estimated to reach 2.4 times this amount by 2020 with projected conditions of flood plain development unless additional protection works and management actions are undertaken for their prevention.

There is an increasing need for extension of a waterway in the Big Sandy River subbasin for transport of coal. New locks and dams will be required to satisfy potential demands for waterborne commerce of 650 million ton-miles annually by 2020.

Additional electric power generation will be required to support the general growth of the economy. Projections to 1980 indicate that generating capacity installed in the three subbasins will be in thermal plants. By 2020, investigations may prove the feasibility of developing the hydroelectric potential to provide a portion of the peaking capacity that will be required in the Ohio Basin.

Upstream watersheds and other areas need attention to assist in retarding overland flows and reduce sediment transport to streams. By 2020, land area requiring treatment and proper management for efficient use is projected to increase to about 1.7 million acres, including a minor amount of irrigation and drainage development. Thirty-four thousand acres, or nearly 80 percent of the lands disturbed by strip mining, are in need of rehabilitation.

The demand for outdoor recreation is predicted to increase many times by 2020. This demand will require full utilization of all resource potentials affiliated with water resource development provisions.

3. <u>Resource Availability</u>. The water resource development potential of the Guyandotte, Big Sandy and Little Sandy subbasins is one of the best in the Ohio Basin. Although generally not of large capacity, reservoir sites are plentiful. Surface runoff is high, and ground water supplies are good in many areas.

The rugged topography and lack of major urban or industrial developments in the tributary valley areas provide favorable opportunities to develop stream regulation reservoirs. Fifteen potential reservoirs with a total storage potential of 471,000 acre-feet have been investigated in some detail and are considered feasible. Twenty-seven potential upstream watershed projects have been investigated covering 1,988 square miles. These projects include 109 upstream detention structures with a potential gross storage capacity of 410,000 acre-feet.

Because of the entrenched streams, pumped storage power projects with high heads may prove to be feasible in the future, although there has been no inventory for identification of sites.

Ground water in large supply is available from sandstones in the upper half of the area. In the lower part of the subbasins aquifers are less productive, but medium yields can be developed in some areas. The lower reach of the Guyandotte Basin lacks a good aquifer, and storage regulation of surface waters will be required to supply demand for water.

The subbasins have extensive scenic and wooded areas available which can be developed for outdoor recreation opportunity and wildlife management.

4. Assessment of Resource Development Requirements. Principal flood problem areas, together with reservoirs and upstream watershed projects in the going program of development and those identified as potential future projects, are shown on the map of the subbasins figure GU-1. Summary data for projects in the going program are given in Appendix K, tables 15 through 21 and for identified potential projects in tables 24 through 28. The relationship of problem areas and projects in the going program is shown schematically in figure GU-2, and key data relating to problem areas are given in table GJ-2. The schematic diagram was used for general orientation in analyzing problems and needs and establishing development requirements for streamflow control. An accounting of storage capacity for streamflow control is given in table GU-3. Results of the assessment of the subbasins to determine the magnitude and costs of resource development required to satisfy projected demands for water and related functions and services are summarized in table GU-4.

a. Requirements to be Furnished by Identified Resource Potential. No specific areas in need of additional water supply or water quality improvement by 2020 have been identified. Most of the 1980 general needs of the subbasins can be met by ground water and existing reservoirs aided by the identified potential flood control reservoirs and upstream watershed projects. Joint use of flood storage for control of low flows will meet many of the early needs.

Total storage capacity required to provide streamflow control is estimated to be about 1.5 million acre-feet in addition to the amount that will be made available upon completion of the going program. About 1,267,000 acre-feet of reservoir capacity will be required for control of flood flows, a large share of which is needed for control of the Standard Project Flood on the Ohio River. In addition, local protection work at 6 locations involving 21 miles of levees and walls and 60 miles of channel improvements in potential watershed projects will be required. About 219,000 acre-feet of storage capacity will be required to make water available to supplement streamflows during low flow periods. The low flow control storage is primarily for replacement of projected municipal, industrial and thermal electric cooling consumptive use losses and sustain adequate streamflow in the

lower reaches of the tributaries affected by the backwater of Greenup navigation pool. The ground water potential is considered more than adequate to provide the 61 million gallons per day toward satisfying 2020 water requirements. Of the total required storage, 684,200 acre-feet would be furnished in identified potential reservoirs including 99,200 acre-feet of joint use space and 146,300 in upstream watershed projects.

A modern navigation system on the Big Sandy River and tributary Levisa Fork would enhance the development of the region. By 2020, it is expected that the project will be needed to satisfy projected demand for low-cost transport of the coal in the area. Improvements would include a 12-foot-deep waterway extending 127 miles from the Ohio River to mile 100 on the Levisa Fork of the Big Sandy River.

Total area in potential feasible upstream watershed projects in the Guyandotte and Big sandy subbasins is about 1.3 million acres. Of this amount, it is estimated that approximately 750 thousand acres of land, 90 percent of it in woodland, will require treatment and management to enhance productivity and serve other beneficial purposes. Retardation of runoff, control of erosion, and reduction of sediment transport to streams are important considerations.

The availability of reservoirs, impoundments, and other developments would provide potential opportunities for 7.5 million outdoor recreation-days annually if access and facilities are made available.

b. Remaining Requirements. A relatively small amount of storage, about 31,000 acre-feet, will be required to supplement streamflows during low flow periods. The 771,000 acre-feet of flood storage capacity for which additional development will be required is the remaining amount needed in the Guyandotte and Big Sandy subbasins to assist in regulating the Ohio River Standard Project Flood down to the maximum flood stage of record.

The excellent fishing and hunting areas and new and expanded outdoor recreation facilities in the three subbasins will help supply the water-oriented, recreational needs of neighboring subbasins where resources may be relatively lacking. The extent to which demand for outdoor recreation opportunity can be satisfied beyond that provided by identified developments has not been assessed. A portion of the remaining requirement can be met in conjunction with other needed water resource developments in the subbasin.

Remaining land treatment and management requirements are associated with the general land base outside watershed projects. By the

year 2020, approximately 950 thousand acres of predominantly woodland, but including cropland and pasture, would be subject to treatment and management measures, some of the more common being contour farming of all types, controlled grassland farming, and improved forest management and utilization. These lands are accounted for in the general inventory of requirements but are not identified by specific location.

TABLE GU-1

GUYANDOTTE, BIG SANDY, LITTLE SANDY SUBBASINS
DEMAND FOR WATER AND RELATED FUNCTIONS AND SERVICES

	Unit	Base Year Amount	Projected Increase[1] 1980	2020
Water Withdrawal				
Municipal and Industrial[2]	Million Gallons Per Day	67.3	22.8	128.0
Electric Power Cooling	Million Gallons Per Day	156	212	303
Rural Communities	Million Gallons Per Day	28.4	0.2	2.3
Rural Domestic and Livestock	Million Gallons Per Day	2.29	0	0.37
Irrigation[3]	Million Gallons Per Day	0.4	0	0.3
Stream Assimilation of Organic Waste Effluent[4]	1,000 Population Equivalents	11.0	0	0
Flood Damage Prevention[5]	Million Dollars Annually	2.88	4.68	9.39
Waterway Freight Movement[6]	Billion Ton-Miles Annually	0	0.25	0.65
Hydroelectric Power - Installed Capacity	Megawatts	0	(Assessed on a basin-wide basis)	
Outdoor Recreation	Million Recreation Days	0.4	11.0	29.6
Sport Fishing	Million Angler Days	1.0	0 [7]	0 [7]
Hunting	Million Hunter Days	0.98	0.04 [7]	0 [7]
Commercial Fishing			(Assessed on a basin-wide basis)	
Land Treatment and Management	1,000 Acres	0	663	1,697
Drainage	1,000 Acres	10	12	17
Irrigation (Land Area)	1,000 Acres	0.6	0.2	1.0

NOTES: (1) Base year amounts plus projected increase equals gross demands.

(2) Mining industry water requirements not included; assessed on a basin-wide basis.

(3) Withdrawal shown is for average year; drought year may be 45 percent higher.

(4) Residual biochemical oxygen demand after 85 percent waste removal by treatment.

(5) The dollar amounts (1980 and 2020) are indices to the magnitude of the problem and the protection measures required to reduce the potential damaging effects of floods.

(6) An index to the canalization and waterway facilities required to accommodate the transport of waterborne freight.

(7) Net requirements.

TABLE GU-2

GUYANDOTTE, BIG SANDY, LITTLE SANDY SUBBASINS
PRINCIPAL CONSIDERATIONS IN DETERMINING STORAGE CAPACITY REQUIREMENTS
FOR CONTROL OF STREAMFLOW

A. SUPPLEMENTAL STREAMFLOW REQUIRED AT KEY LOCATIONS TO CONTROL WATER QUALITY (CFS).

No problem areas within the scope of this study.

B. WATER REQUIRED TO SATISFY DEMANDS FOR WITHDRAWAL AND USE (IN ADDITION TO THAT PROVIDED IN BASE YEAR) (MGD).

Item	1980	2020
1. Total withdrawal (1)	235	434
2. To be provided by groundwater	11	61
3. Total consumptive use	3	14

C. FLOOD DAMAGE AREAS

Location	Residual Damages (2) (Millions Dollars)	
1. Upstream areas	2.87	
2. Major urban areas (3)	0.47	
Martin, Ky, Beaver Creek Paintsville, Ky, Paint Creek Inez, Ky, Rockcastle Creek Grundy, W Va, Levisa Fork Matewan, W Va, Tug Fork Williamson, W Va, Tug Fork		
3. Other flood plain areas	0.60	
4. Total subbasin	3.94	Projected to 4.68 in 1980 and 9.39 in 2020.

NOTES: (1) Water required to satisfy municipal and industrial, electric power cooling, rural community, rural domestic and livestock, and irrigation demands.

(2) Estimated average annual damages with the 1965 flood control program completed (1965 constant dollars).

(3) See figure GU-1 for geographic location of principal problem areas and figure GU-2 for schematic relationship.

TABLE GU-3

GUYANDOTTE, BIG SANDY, LITTLE SANDY SUBBASINS
ACCOUNTING OF STORAGE CAPACITY FOR STREAMFLOW CONTROL
(IN ADDITION TO THAT PROVIDED IN THE GOING PROGRAM)

	Time Period 1980	Time Period 2020
	Storage (1,000 Ac Ft)	
A. WATER QUALITY CONTROL.		
1. Storage required(1)	0	0
2. Storage provided in identified potential sites	0	0
3. Additional storage required	0	0
B. WATER WITHDRAWALS.		
1. Storage required	42.6	219.0
C. FLOOD CONTROL.		
1. Subbasin and Ohio River control requirement	389.7	1,267.3
2. Storage provided in identified potential sites	196.9	496.3
a. *for solving localized problems*	(64.7)	(146.3)
b. effective in controlling both subbasin and Ohio River flows	(132.2)	(350.0)
3. Additional storage required(2)	192.8	771.0
D. TOTAL STORAGE REQUIREMENT.		
1. Water quality control, water withdrawals, and flood control	432.3	1,486.3
2. Available in identified potential sites(3)	226.5	584.9
3. Joint use storage	13.0	99.3
4. Additional storage required(4)	192.8	802.1

NOTES: (1) Storage capacity required to provide supplemental flows at key urban locations and rural communities in upstream watershed areas.

(2) Remaining Guyandotte, Big Sandy, Little Sandy subbasins share of storage required to reduce the Ohio River Basin Standard Project Flood to the maximum flood stage of record.

(3) See figure GU-1.

(4) Terrain indicates storage sites are potentially available.

TABLE GU-4

GUYANDOTTE, BIG SANDY, LITTLE SANDY SUBBASINS
SUMMARY ASSESSMENT OF RESOURCE DEVELOPMENT REQUIREMENTS

Program Elements	Unit	Provided in Going Program	Additional Requirement (1) 1980 Amount	1980 Capital Cost ($1,000)	2020 (Accumulative) Amount	2020 Capital Cost ($1,000)
PART 1. TO BE FURNISHED BY IDENTIFIED RESOURCE POTENTIAL WITHIN SUBBASIN.						
A. Streamflow Control and In-Stream Use						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	114.7	29.6	6,600	88.6	21,700
2. Control of Flood Flows						
a. reservoir and detention storage	1,000 Ac Ft	521.0	196.9	49,100	496.3	126,200
b. local protection projects	Miles	0.4	4.3	3,500	21.0	10,500
c. channel improvement	Miles	0	27	2,900	60	5,400
3. Navigable Waterway						
a. improvement to existing waterway	Miles of Channel	0	-	-	-	-
b. new waterway	Miles of Channel	-	0	0	127	200,000
c. channel deepening to 12 feet	Miles of Channel	-	-	-	-	-
4. Hydroelectric Power - Installed Capacity	Megawatts	0	0	0	(Assessed on a Basin-wide Basis)	
B. Related Programs						
1. Outdoor Recreation (2)(3)	Million Recreation Days	0.4	2.4	9,300	7.5	27,700
2. Watershed Project Land Treatment and Management (4)	1,000 Acres	0	336.0	8,400	754.5	18,900
COSTS - PART 1				79,800		410,400
PART 2. REMAINING REQUIREMENTS.						
A. Streamflow Control and In-Stream Use (5)						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	-	0	0	31.1	7,900
2. Storage for Control of Flood Flows	1,000 Ac Ft	-	192.8	49,200	771.0	196,600
3. Hydroelectric Power			(Assessed on a Basin-wide Basis)			
B. Related Programs						
1. Outdoor Recreation (2)(6)	Million Recreation Days	-	8.6	30,000	22.1	77,300
2. Fish and Wildlife						
a. sport fishing (2)(6)	Million Angler Days	1.00	0	0	0	0
b. hunting (2)(6)	Million Hunter Days	0.98	0.04	100	0	0
c. commercial fishery			(Assessed on a Basin-wide Basis)			
C. Land Treatment and Management						
1. Lands Outside Watershed Projects	1,000 Acres	-	326.9	8,200	943.0	23,600
2. Irrigation (Acres to be Irrigated)	1,000 Acres	0.6	.2	-	.5	100
3. Drainage	1,000 Acres	10	10.6	1,700	15.0	2,400
COSTS - PART 2				89,200		307,900
TOTAL COSTS - (PARTS 1 AND 2)				169,000		718,300

NOTES:
(1) Requirement in addition to that provided by going development programs.

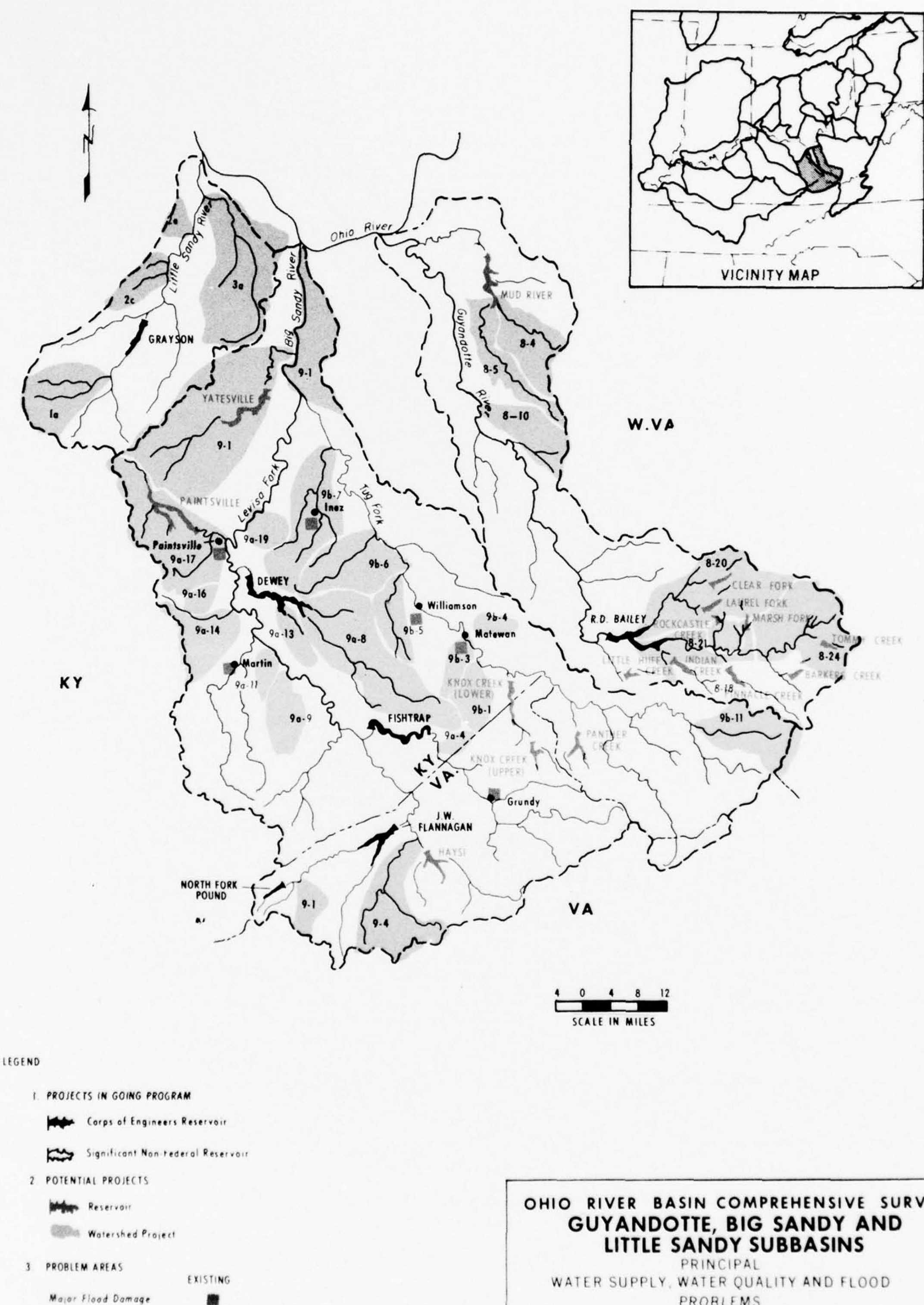
(2) Costs shown are for initial facilities and such measures as may be required to implement the program, and do not include water and related land cost. Base year 1960.

(3) The number of outdoor recreation days shown include some sport fishing and hunting which could not be separately accounted for in available data.

(4) Land area and costs shown are for total land treatment and management requirements in watershed projects and cover both water resource development related and other lands.

(5) Specific sites to provide storage capacity for streamflow control are not identified; however, favorable storage sites are potentially available.

(6) Because of population and resource distributions, remaining subbasin requirements for outdoor recreation, sport fishing and hunting not satisfied by water resource developments may require a trade off with adjacent subbasins or satisfied by other means.



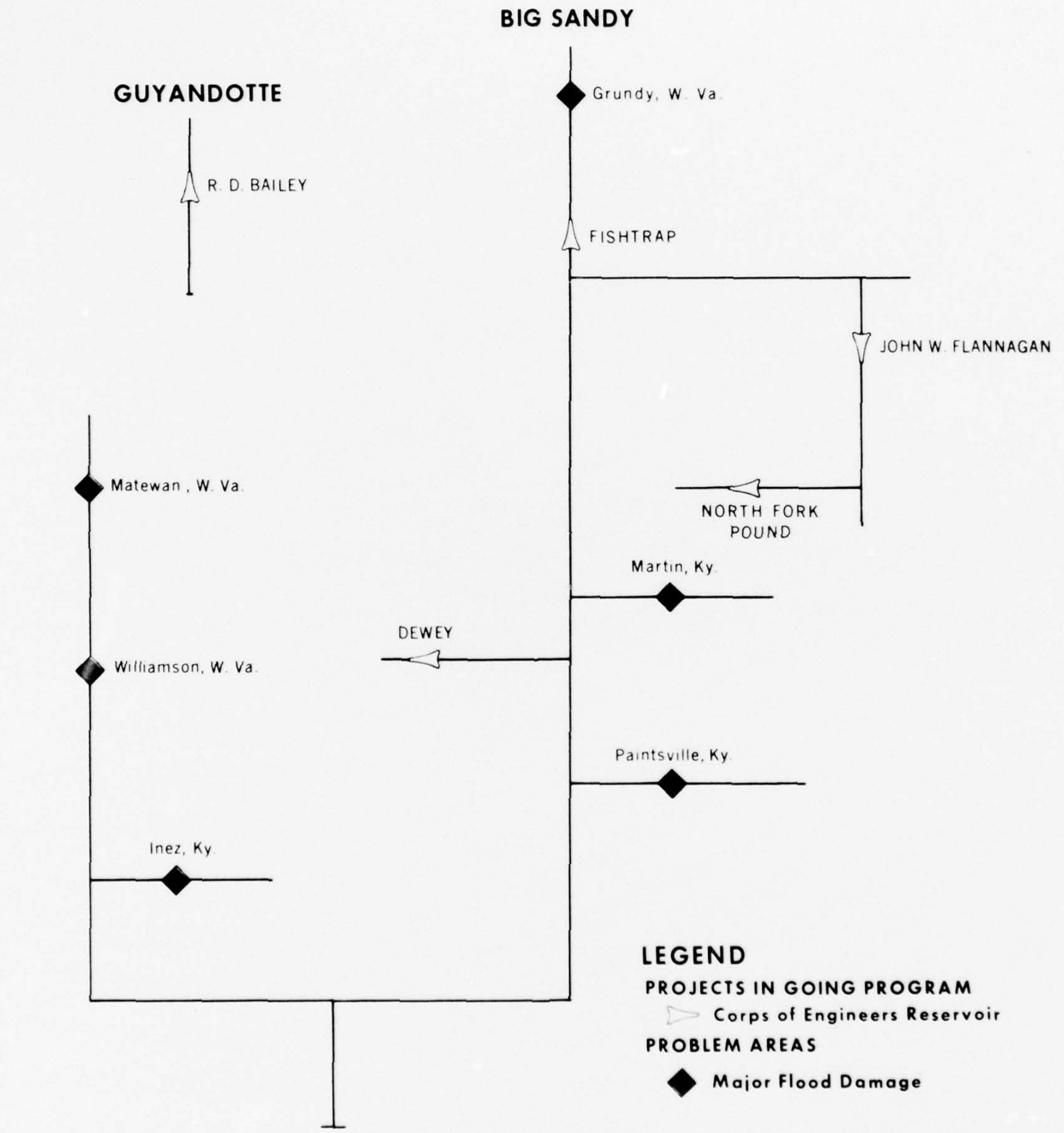
OHIO RIVER BASIN COMPREHENSIVE SURVEY

GUYANDOTTE, BIG SANDY AND LITTLE SANDY SUBBASINS

PRINCIPAL
WATER SUPPLY, WATER QUALITY AND FLOOD
PROBLEMS

RESERVOIRS AND WATERSHED PROJECTS
IN GOING PROGRAM, AND POTENTIALS

CORPS OF ENGINEERS — U.S. ARMY OHIO RIVER DIVISION
APPENDIX K — FIGURE GU-1



Note: There are no present or projected water supply or water quality control problem areas in the Guyandotte and Big Sandy River Basins.

OHIO RIVER BASIN COMPREHENSIVE SURVEY

GUYANDOTTE AND BIG SANDY SUBBASINS ANALYSIS SCHEMATIC

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE GU-2

SCIOTO

1. Planning Environment. The Scioto River subbasin, situated in the north-central portion of the Ohio Basin, contains 6,510 square miles, or nearly four percent of the study area. It lies entirely within the State of Ohio. The land in the upper area is a glacial plain which extends southward through rolling terrain and ends in the rugged unglaciated plateau region near the Ohio River.

The Scioto subbasin has a history of recurring heavy rains and summer thunderstorms with intense rainfall, often causing floods. In contrast, extended droughts, although infrequent, have caused major crop losses and acute water supply shortages. Average annual runoff per unit of area has been less than that for the Ohio Basin. The growing season approximates the Ohio Basin average of 200 days.

The Scioto subbasin was settled in the late 1700's. The early immigrants were attracted by the rich soil and bountiful forests and wildlife. Many small urban centers and rural communities stemmed from this early beginning. Columbus, the state capital near the center of the subbasin, has developed into a major industrial and commercial center.

The Scioto subbasin accounts for about six percent of the population, labor force and industrial output of the Ohio Basin study area. Projective economic studies indicate that the general economy of the Scioto subbasin will continue to grow at a greater rate than that of the overall Ohio Basin.

2. Demand for Water and Related Functions and Services. Efficient management of water and related land resources, additional development and diligent prosecution of programs allied to water and land use will be required to keep pace with projected demands within the Scioto subbasin. Base year and projected increases that comprise gross demands for water and related functions and services are listed in table SI-1. Table SI-2 provides principal considerations in determining storage capacity requirements for control of streamflow.

The concentration of economic activity at Columbus, the largest city in the Scioto subbasin, and at other communities has resulted in large demands for water, the control of floods, outdoor recreation, and has created problems associated with municipal and industrial waste effluents and other stream pollution.

In general, annual runoff is adequate in quantity and, if properly controlled, sufficient to fulfill future demands for water. Approximately 85 percent of the municipal and industrial water supply requirement in the Scioto River subbasin is concentrated in the highly industrialized area near Columbus.

Improvement of water quality is a major concern throughout the Scioto subbasin. The quality of ground water in many areas is impaired by a high degree of hardness.

Land treatment and management and additional irrigation and drainage will be required to develop the full economic potential of the land resource.

Flooding is still a problem at many locations; Chillicothe and Columbus are high damage centers.

There is no commercial navigation in the Scioto subbasin. Industry and other activities in the basin produce and consume large quantities of bulk products suitable for waterborne transport. However, the resource development potentials of the basin are unfavorable in relation to the magnitude of the demand to support an efficient navigable waterway.

The Columbus metropolitan area is in need of additional outdoor recreation facilities and if the projected future outdoor recreation, fishing and hunting desires are to be satisfied, further sources of water-based opportunity will be needed. Realization of the substantial potential for recreation development within the subbasin will require the provision of ready access to the resource areas and the construction of adequate facilities.

a. Going Program Accomplishments. Development and management programs by Federal, state and local interests have generally kept pace with critical development needs. The State of Ohio has completed a water inventory of the Scioto subbasin. Research and reclamation efforts have been initiated to solve problems of control of organic and silt pollution of streams. Over 1.2 million acres of agricultural land have been drained and about 3,400 acres receive supplemental water for irrigation.

The Delaware Reservoir was the only Federal storage project existing in 1965; three were under construction and one in preconstruction planning stage. The five projects will provide a total of 571 thousand acre-feet of storage for control of floods and about 32 thousand acre-feet of storage in joint use for low flow supplementation. They will control runoff from about 30 percent of the total subbasin area. Two non-Federal local protection projects provide additional protection from flood flows. The foregoing projects would prevent an estimated 490 thousand dollars or only 11 percent of the potential average annual flood damages in downstream areas under 1965 conditions of flood plain developments. No protective works of significance have been constructed in upstream areas. In 1965, there were no authorized upstream watershed projects.

Flowing streams within the subbasin have been tapped as the principal source for satisfying major municipal and industrial water demands. Griggs, Hoover, and O'Shaughnessy Reservoirs furnish a major portion of

the water supply requirements of the Columbus area. Over three-fourths of the total water demand in the Scioto subbasin is in the Columbus area. Rural water needs are served primarily from ground water sources. Fifty percent of the municipal withdrawals outside of Columbus are taken from ground water.

Recreation facilities at reservoirs and along natural streams have been provided by Federal and non-Federal interests. State parks, state forests and other recreation areas exist in the subbasin. Stream pollution cleanup efforts have enhanced these programs in many reaches. Development and management programs have been put into effect to improve land cover and provide facilities for recreation, hunting and fishing throughout the subbasin. The 1960 use was 4.7 million recreation days, 1.5 million angler days and 530 thousand hunter days.

b. Future Demand. Projected requirements of the expanding economy, which will intensify demand for further use, development, and management of water and related land resources, are shown in table SI-1.

It will be noted that municipal and industrial water supply withdrawals existant in 1960 will increase about 3.5 times by 2020, increasing from about 136 million gallons per day to 466 mgd. Additional streamflow to provide waste assimilation capacity within acceptable standards of quality is now needed to absorb organic waste loads. Much more will be required in the future, as wastes are projected to increase almost 3.5 times the 1960 loads by 2020. The Columbus-Circleville-Chillicothe area is the most critical. The flow in this reach of the Scioto River provided by the going program is 41 cfs. The 1980 requirement is 434 cfs increasing to 739 cfs by 2020. It should be noted that this is 18 times as great as the flow available with the going program.

Only 7.5 percent of the potential natural damages from flood flows would be prevented by the going program for flood control. Protection works and management programs will be needed to prevent potential flood damages projected by 2020 to be nearly four times the 1965 residual annual average of $6 million.

The demand for outdoor recreational opportunities is predicted to increase over tenfold by 2020. This demand, in conjunction with increased hunting and fishing pressure, will require full utilization of all resource potentials affiliated with water resource developments.

By 2020, nearly three million acres of land will require treatment and management measures. The economic potential for agriculture irrigation and agricultural land drainage is the third highest in the Ohio River Basin; irrigated land area is projected to increase 163,400 acres by 2020 and additional land that can be economically drained, 580,000 acres.

3. Resource Availability. The potential for storage control of surface waters of the Scioto subbasin in relation to need is limited. Reservoir sites are not plentiful, but are adequate to meet needs projected for 2020.

Five potential reservoirs with a total storage capacity of about 350 thousand acre-feet have been investigated in some detail. Construction of these projects would control runoff from 20 percent of the subbasin area, increasing the total area controlled to 50 percent. There are 20 potentially feasible upstream watershed projects containing sites for 85 water detention structures having a total of about 277 thousand acre-feet of storage capacity which would provide control of 497 square miles of watershed area.

Ground water in large supplies is available in the northern part of the subbasin and along the Scioto River and major tributary valleys. Along the Olentangy River and Alum Creek and in the Scioto River Valley below Columbus, sand and gravel aquifers have high yields. Because of limited ground water, conservation of surface waters will be required to supply water demands in the southern part of the subbasin outside the immediate valley of the Scioto River.

There is no known hydroelectric power potential practical of development.

The subbasin has many scenic and wooded areas which can be utilized for outdoor recreation development and wildlife management.

4. Assessment of Resource Development Requirements. The subbasin map, figure SI-1, shows the principal water supply, water quality and major urban flood problem areas, together with reservoirs in the going program of development and those identified as potential future projects. Also shown are potential upstream watershed projects. Summary data for projects in the going program are given in Appendix K, tables 15 through 19 and for identified potential projects in tables 24 through 27. The relationship of problem areas and projects in the going program is shown schematically in figure SI-2 and key data relating to problem areas are given in table SI-2. The schematic diagram was used for orientation in the analysis for establishing development requirements for streamflow control. An accounting of storage capacity for streamflow control is given in table SI-3. Results of the subbasin assessment to determine the magniutde and costs of resource development required to satisfy projected demands for water and related functions and services are summarized in table SI-4.

a. Requirements to be Furnished by Identified Resource Potential. The analysis of demand for water and related functions and services and of the means whereby these demands can be satisfied indicates that the solution to water supply and particularly water quality

and flood problems, will require development of additional storage capacity for streamflow control. The analysis further demonstrates the need for local protection projects and channel improvement in critical locations, either singly or in combination with regulation of streamflow, to best cope with the flood problems.

The aggregate total storage space needed by 2020 to provide required streamflow control in addition to the going program of resource development is estimated to be about 2.2 million acre-feet. About 1.3 million acre-feet will be required for the control of flood flows and about 877,000 acre-feet to provide for low flow requirements. The flood control plan for the Scioto subbasin in addition to developments in the going program, consists of utilization of 239,000 acre-feet of the reservoir space in the five identified potential reservoirs for flood storage; 62,000 acre-feet or about 22 percent of the storage capacity in potential upstream watershed projects for floodwater retardation and 497 miles of channel improvement in agricultural flood plain; and one small and six major urban local protection projects. In addition, flood plain management must be established as an integral part of the overall flood protection and flood damage prevention program.

Thirty-four areas needing additional water supply or water quality improvement by 2020 have been identified. About 246,000 acre-feet of storage capacity to serve these areas can be provided in identified potential developments. Storage capacity in potential upstream watershed detention structures would be approximately 87,000 acre-feet, and in identified reservoirs, 99,000 acre-feet; the remaining 60,000 acre-feet is flood storage space available for joint use. The ground water potential is considered more than adequate to furnish 107 mgd toward satisfying water withdrawal demands.

The potential reservoirs, watershed projects and availability of clean streams could provide opportunities for over 11 million recreation days if adequate access and facilities are made available.

Total area in potential feasible upstream watershed projects is about two million acres. Of this amount, it is estimated that approximately 1.1 million acres of cropland, pasture, and woodland will require treatment and management to enhance land productivity and serve other beneficial purposes. Retardation of runoff, control of erosion, and reduction of sediment transport to streams are important considerations.

The magnitude of the water resource development and related items furnished by identified resources are summarized in Part I, table SI-4.

b. Remaining Requirements. Storage capacity of 630 thousand acre-feet at unidentified sites is required to supplement streamflows during low flow periods to provide quality control and furnish water for withdrawal and use. It includes an amount for water required in

areas not identified by specific location of need and an amount required to provide stream regulation in several identified areas of need, but for which storage developments are not identified. Reservoir storage potential in the Scioto subbasin is physically limited and advanced waste treatment may prove more economical or even a necessity in the future, particularly near Columbus and in upstream areas.

Storage capacity that can be made available in identified potential projects is sufficient to provide for subbasin flood control requirements and would also furnish a portion of the capacity required for flood stage reduction on the Ohio River. The approximate one million acre-feet for which additional development will be required is the remaining amount needed in the Scioto subbasin to assist in regulating the Ohio River Standard Project Flood.

The extent to which demand for outdoor recreational opportunity can be satisfied at other locations beyond that provided by identified developments has not been defined. A portion of the remaining requirement can be met in conjunction with other needed water resource developments in the subbasin. However, to satisfy recreation requirements beyond the potentials associated with water resource developments particularly for the Columbus metropolitan area, other recreation developments and utilization of resources in other subbasins will be required.

Remaining land treatment and management requirements are associated with the general land base outside potential watershed projects, with exception that lands to be irrigated or drained may be located in or outside watershed projects. By the year 2020, approximately 1.0 million acres of cropland, pasture, and woodland would be subject to treatment and management measures, some of the more common being contour farming of all types, controlled grassland farming, and improved forest management and utilization. Land area to receive supplemental irrigation water is 156,000 acres and that to be drained, 442,500. These lands are accounted for in the general inventory of requirements but are not identified by specific location.

Part 2 of table SI-4 is a summary of remaining items to be provided by unidentified sites and assessed in the Ohio River and basin-wide analysis.

TABLE SI-1

SCIOTO SUBBASIN
DEMAND FOR WATER AND RELATED FUNCTIONS AND SERVICES

	Unit	Base Year Amount	Projected Increase(1) 1980	Projected Increase(1) 2020
Water Withdrawal				
Municipal and Industrial(2)	Million Gallons Per Day	136.3	109.7	466.1
Electric Power Cooling	Million Gallons Per Day	312	0	312
Rural Communities	Million Gallons Per Day	20.9	1.7	11.7
Rural Domestic and Livestock	Million Gallons Per Day	8.39	4.01	12.61
Irrigation(3)	Million Gallons Per Day	1.7	8.4	78.7
Stream Assimilation of Organic Waste Effluent(4)	1,000 Population Equivalents	252.2	189.0	850.7
Flood Damage Prevention(5)	Million Dollars Annually	0.49	9.27	23.14
Waterway Freight Movement(6)	Million Ton-Miles Annually	0	0	0
Hydroelectric Power - Installed Capacity	Megawatts	0	(Assessed on a basin-wide basis)	
Outdoor Recreation	Million Recreation Days	4.7	14.8	46.8
Sport Fishing	Million Angler Days	1.50	0.37(7)	1.30(7)
Hunting	Million Hunter Days	0.53	0.08(7)	0.28(7)
Commercial Fishing			(Assessed on a basin-wide basis)	
Land Treatment and Management	1,000 Acres	0	896	2,340
Drainage	1,000 Acres	1,226	393	485
Irrigation (Land Area)	1,000 Acres	3.4	18.8	163.4

NOTES: (1) Base year amounts plus projected increase equals gross demands.

(2) Mining industry water requirements not included; assessed on a basin-wide basis.

(3) Withdrawal shown is for average year; drought year may be 45 percent higher.

(4) Residual biochemical oxygen demand after 85 percent waste removal by treatment.

(5) The dollar amounts (1980 and 2020) are indices to the magnitude of the problem and the protection measures required to reduce the potential damaging effects of floods.

(6) An index to the canalization and waterway facilities required to accommodate the transport of waterborne freight.

(7) Net requirements.

TABLE SI-2

SCIOTO SUBBASIN
PRINCIPAL CONSIDERATIONS IN DETERMINING STORAGE CAPACITY REQUIREMENTS
FOR CONTROL OF STREAMFLOW

A. SUPPLEMENTAL STREAMFLOW REQUIRED AT KEY LOCATIONS TO CONTROL WATER QUALITY (CFS).

Problem Area[1]	Stream	Required Flow[2] 1980	Required Flow[2] 2020	Flow Provided by Going Program	Supplemental Flow Required 1980	Supplemental Flow Required 2020
Kenton	Scioto River	19	40	3	16	37
Columbus-Circleville-Chillicothe	Scioto River	475	780	41	434	739
Sabina	Wilson Creek	3	20	5	0	15
Plain City	Big Darby Creek	4	20	5	0	15
Marion	Little Scioto River	75	145	2	28	143
Richwood	Fulton Creek	4	20	5	0	15
Marysville	Mill Creek	16	40	1	15	39
Galion	Olentangy River	30	55	1	29	54
Mt. Gilead	Whetstone Creek	11	30	5	6	25
Reynoldsburg	Blacklick Creek	11	30	5	6	25
Westerville	Alum Creek	11	20	5	6	15
West Jefferson	Little Darby Creek	4	30	5	0	25
London	Deer Creek	12	30	5	6	25
Greenfield	Paint Creek	16	40	3	13	37
Hillsboro	Rocky Fork Creek	11	30	5	6	25
Washington Court House	Paint Creek	30	55	3	27	52
Jackson	Little Salt Creek	13	20	5	6	15

B. WATER REQUIRED TO SATISFY DEMANDS FOR WITHDRAWAL AND USE (IN ADDITION TO THAT PROVIDED IN BASE YEAR) (MGD).

Item	1980	2020
1. Total withdrawal[3]	126	565
2. To be provided by groundwater	25	107
3. Total consumptive use	22	167

C. FLOOD DAMAGE AREAS.

Location	Residual Damages[4] (Millions Dollars)	
1. Upstream areas	1.97	
2. Major urban areas[1]	1.76	
LaRue, Scioto River Kenton, Scioto River Washington C.H., Paint Creek Chillicothe, Scioto River Columbus, Scioto & Olentangy Rivers, Alum & Big Walnut Creeks		
3. Other flood plain areas	2.28	
4. Total subbasin	6.01	Projected to 9.27 in 1980 and 23.14 in 2020.

NOTES: (1) See figure SI-1 for geographic location of principal problem areas and figure SI-2 for schematic relationship.

(2) Streamflow required to maintain a minimum of 4 parts per million of dissolved oxygen.

(3) Water required to satisfy municipal and industrial, electric power cooling, rural community, rural domestic and livestock, and irrigation demands.

(4) Estimated average annual damages with the 1965 flood control program completed (1965 constant dollars).

TABLE SI-3

SCIOTO SUBBASIN
ACCOUNTING OF STORAGE CAPACITY FOR STREAMFLOW CONTROL
(IN ADDITION TO THAT PROVIDED IN THE GOING PROGRAM)

	Time Period 1980	Time Period 2020
	Storage (1,000 Ac Ft)	
A. WATER QUALITY CONTROL.		
1. Storage required(1)	275.4	466.6
2. Storage provided in identified potential sites	4.6	4.6
3. Additional storage required	270.8	462.0
B. WATER WITHDRAWALS.		
1. Storage required	35.6	410.2
C. FLOOD CONTROL		
1. Subbasin and Ohio River control requirement	414.6	1,316.1
2. Storage provided in identified potential sites	160.8	301.1
a. for solving localized problems	(24.8)	(62.1)
b. effective in controlling both subbasin and Ohio River flows	(136.0)	(239.0)
3. Additional storage required(2)	253.8	1,015.0
D. TOTAL STORAGE REQUIREMENT.		
1. Water quality control, water withdrawals, and flood control	725.6	2,192.9
2. Available in identified potential sites(3)	261.6	487.3
3. Joint use storage	32.2	60.2
4. Additional storage required(4)	431.8	1,645.4

NOTES: (1) Storage capacity required to provide supplemental flows at key urban locations and rural communities in upstream watershed areas.

(2) Remaining Scioto subbasin share of storage required to reduce the Ohio River Basin Standard Project Flood to the maximum flood stage of record.

(3) See figure SI-1.

(4) Terrain indicates storage sites are potentially available.

TABLE SI-4

SCIOTO SUBBASIN
SUMMARY ASSESSMENT OF RESOURCE DEVELOPMENT REQUIREMENTS

Program Elements	Unit	Provided in Going Program	Additional Requirement[1] 1980 Amount	1980 Capital Cost ($1,000)	2020 (Accumulative) Amount	2020 Capital Cost ($1,000)
PART 1. TO BE FURNISHED BY IDENTIFIED RESOURCE POTENTIAL WITHIN SUBBASIN.						
A. Streamflow Control and In-Stream Use						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	31.7	100.8	22,300	186.2	36,800
2. Control of Flood Flows						
a. reservoir and detention storage	1,000 Ac Ft	571.4	160.8	49,500	301.1	77,300
b. local protection projects	Miles	0	3.1	4,000	10.3	8,300
c. channel improvement	Miles	0	199	7,900	497	19,800
3. Navigable Waterway						
a. improvement to existing waterway	Miles of Channel	0	-	-	-	-
b. new waterway	Miles of Channel	-	-	-	-	-
c. channel deepening to 12 feet	Miles of Channel	-	-	-	-	-
4. Hydroelectric Power - Installed Capacity	Megawatts	0	0	0	(Assessed on a Basin-wide Basis)	
B. Related Programs						
1. Outdoor Recreation[2][3]	Million Recreation Days	4.7	2.9	10,200	11.6	41,000
2. Watershed Project Land Treatment and Management[4]	1,000 Acres	0	459.6	11,500	1,149.0	28,700
	COSTS - PART 1			105,400		211,900
PART 2. REMAINING REQUIREMENTS.						
A. *Streamflow Control and In-Stream Use*[5]		-				
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	-	178.0	45,400	630.4	160,800
2. *Storage for Control of Flood Flows*	*1,000 Ac Ft*	-	*253.8*	*64,700*	*1,015.0*	*258,800*
3. Hydroelectric Power				(Assessed on a Basin-wide Basis)		
B. Related Programs						
1. Outdoor Recreation[2][6]	Million Recreation Days	-	13.9	48,400	35.2	122,900
2. Fish and Wildlife						
a. sport fishing[2][6]	Million Angler Days	1.50	0.37	1,300	1.30	4,600
b. hunting[2][6]	Million Hunter Days	0.53	0.08	300	0.28	1,000
c. commercial fishery				(Assessed on a Basin-wide Basis)		
C. Land Treatment and Management						
1. Lands Outside Watershed Projects	1,000 Acres	-	436.0	10,900	1,191.2	29,800
2. Irrigation (Acres to be Irrigated)	1,000 Acres	3.4	18.1	1,700	156.0	14,400
3. Drainage	1,000 Acres	1,226	380.2	48,300	442.5	56,200
	COSTS - PART 2			221,000		648,500
	TOTAL COSTS - (PARTS 1 AND 2)			326,400		860,400

NOTES: (1) Requirement in addition to that provided by going development programs.

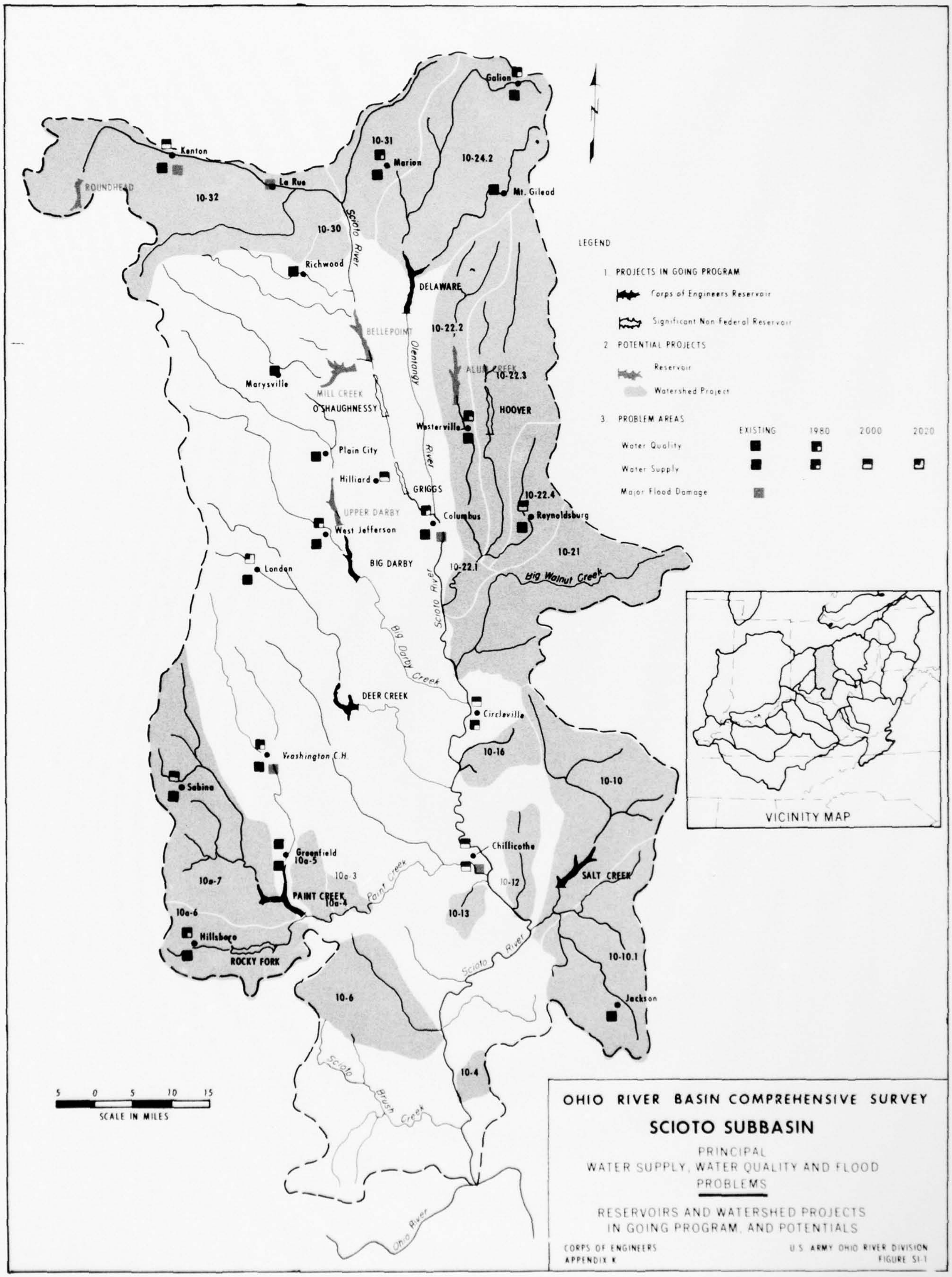
(2) Costs shown are for initial facilities and such measures as may be required to implement the program, and do not include water and related land cost. Base year 1960.

(3) The number of outdoor recreation days shown include some sport fishing and hunting which could not be separately accounted for in available data.

(4) Land area and costs shown are for total land treatment and management requirements in watershed projects and cover both water resource *development related and other lands.*

(5) Specific sites to provide storage capacity for streamflow control are not identified; however, favorable storage sites are potentially *available.*

(6) Because of population and resource distributions, remaining subbasin requirements for outdoor recreation, sport fishing and hunting not satisfied by water resource developments may require a trade off with adjacent subbasins or satisfied by other means.



OHIO RIVER BASIN COMPREHENSIVE SURVEY

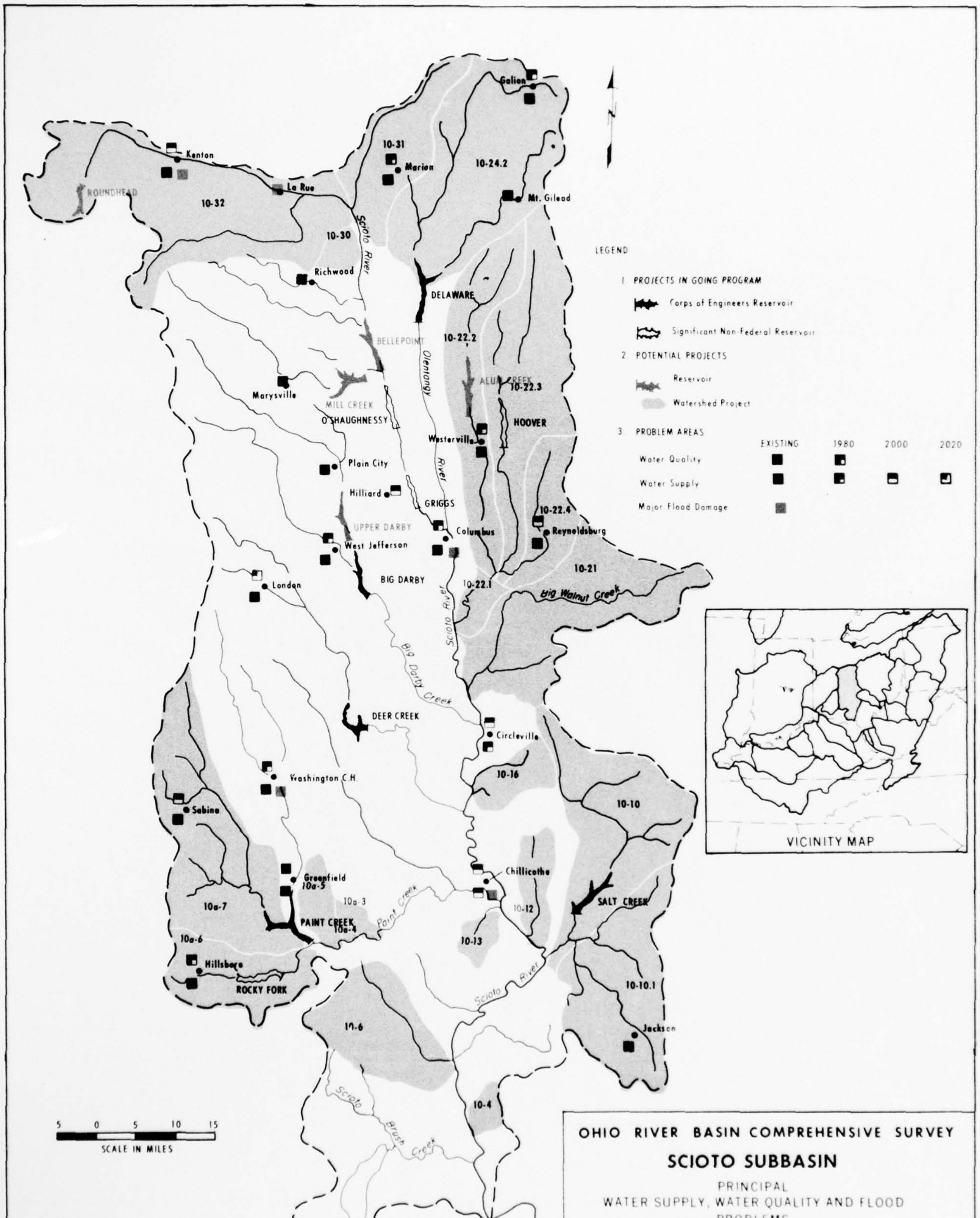
SCIOTO SUBBASIN

PRINCIPAL
WATER SUPPLY, WATER QUALITY AND FLOOD PROBLEMS

RESERVOIRS AND WATERSHED PROJECTS IN GOING PROGRAM, AND POTENTIALS

CORPS OF ENGINEERS
APPENDIX K

U.S. ARMY OHIO RIVER DIVISION
FIGURE SI-1



OHIO RIVER BASIN COMPREHENSIVE SURVEY

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PRINCIPAL
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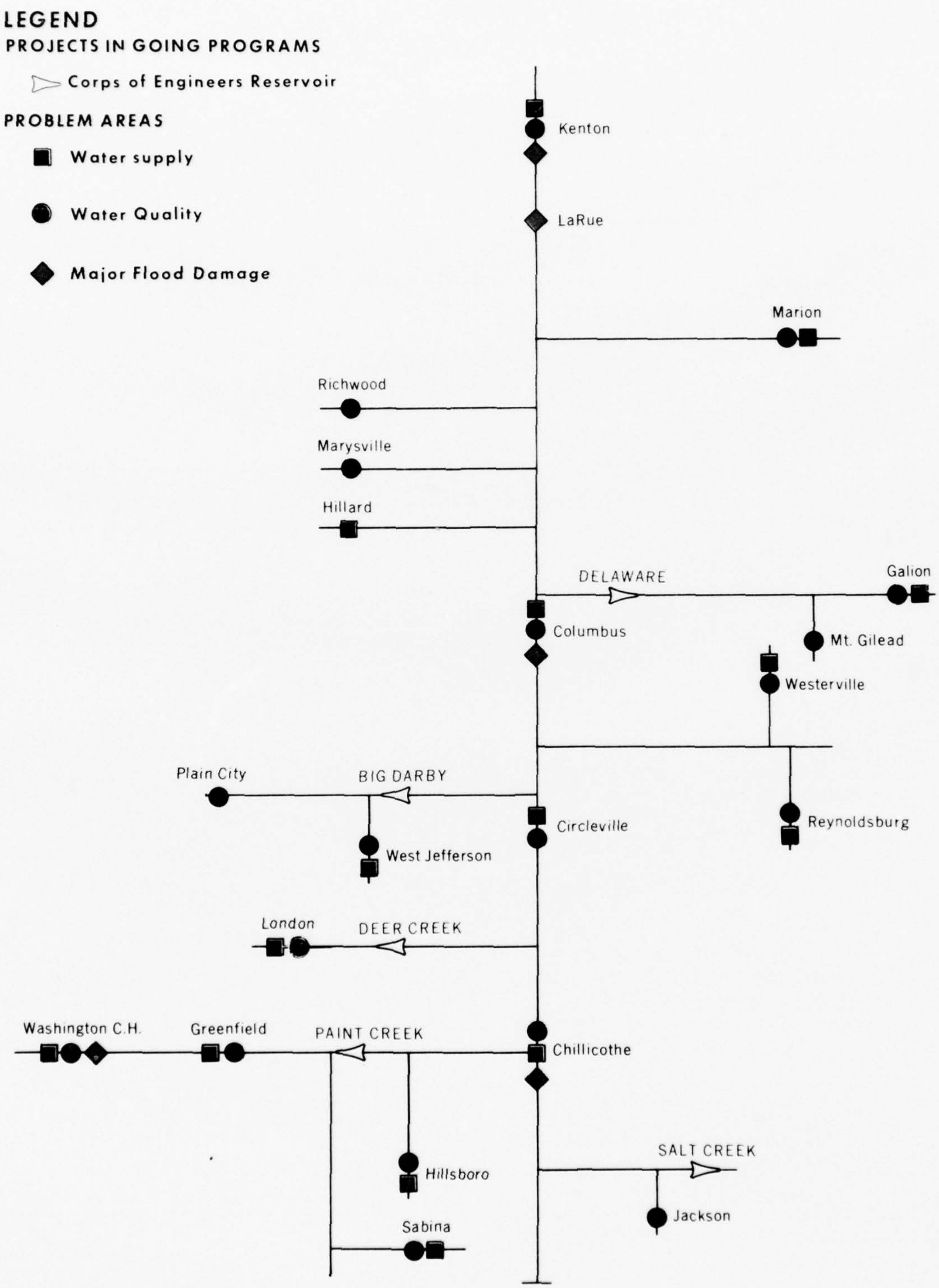
FIGURE SI-1



Note: Subbasin is Located in Ohio

OHIO RIVER BASIN COMPREHENSIVE SURVEY

SCIOTO SUBBASIN
ANALYSIS SCHEMATIC

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION
APPENDIX K FIGURE SI-2

GREAT MIAMI AND LITTLE MIAMI

1. Planning Environment. The Great Miami and Little Miami River subbasins are situated in the north-central portion of the Ohio Basin. The Great Miami subbasin contains 5,400 square miles and the Little Miami, 1,760 square miles. Together, they cover about 4.4 percent of the Ohio Basin study area. The Great Miami subbasin includes portions of southwestern Ohio and southeastern Indiana; but the Little Miami subbasin is entirely in southwestern Ohio. The topography in the upper and middle portions of the subbasins is typified by level to gently rolling plains broken by the wide valleys of the larger streams. In the lower reaches of the subbasins, the terrain changes to rolling and hilly as the rivers near the Ohio River. Portions of the subbasins are heavily forested. Prehistoric Indian tribes found the rich soil and bountiful forests and wildlife suitable for developing advanced cultures.

The climate is generally typical of the central section of the Ohio Basin study area, and the growing season approaches the Basin average. The subbasins have a history of heavy rains and summer thunderstorms with intense rainfall. Runoff per unit of area is less than the average for the Ohio Basin; nevertheless, flooding occurs in many areas. In contrast, extended droughts, although infrequent have caused major crop losses and acute water shortages.

In the early 1800's, immigrants fanned out from the areas along the Ohio River and found the hinterland conditions ideal for a self-contained economy. Many small urban centers and rural communities stemmed from this early beginning. Dayton, Springfield, Middletown, Hamilton and other cities in the area grew rapidly to form one of the major industrial and commercial centers of the nation. The section of the Great Miami River subbasin in the State of Ohio is one of the most highly urbanized in the Ohio Basin. The downstream portion of the Little Miami River subbasin contains a portion of the Cincinnati, Ohio, metropolitan area, while upstream thereof the area is essentially rural in character. A considerable reach of the Little Miami River has unique scenic features and is being considered in Federal scenic river legislation to preserve its natural beauty.

The Great Miami-Little Miami subbasins contain 7.4 percent of the population and 7.8 percent of the labor force in the Ohio Basin study area, and produce 8.4 percent of industrial output. A considerable portion of the economy is based on the steel producing and related automobile and machine tool industries; paper and other manufacturing are also important. Both agricultural and industrial workers live at an economic level above the Ohio Basin average. Though city slums and isolated poverty exist, there are comparatively few people with sub-standard incomes in the area. Projective economic studies indicate that the general economy of the Great Miami-Little Miami area will continue to grow at a greater rate than that of the overall Ohio

Basin. The availability of excellent transportation facilities, and rapid growth in educational and cultural activities are expected to increase the services sector of the economy substantially.

2. Demand for Water and Related Functions and Services. Base year and projected increases that comprise gross demands for water and related functions and services are listed in table GM-1. Principal considerations in determining storage capacity requirements for control of streamflow are provided in table GM-2. The concentration of economic activity, primarily in the Great Miami subbasin, has not only resulted in large demands for water, flood protection, recreation, and other water related functions and services; but has resulted in the aggravation of problems associated with municipal and industrial waste and other stream pollution.

In general, present municipal and industrial water supplies are adequate in quantity. However, to satisfy projected future demands, careful development and control of the available resources will be required. As to quality, both ground and surface waters are hard, and ground water sources generally contain excessive amounts of iron. However, the primary cause for adverse water quality is organic wastes from municipal sewage systems and industrial outfalls. The lack of sufficient streamflow to fully assimilate organic waste loads is a serious problem, particularly along the Great Miami River. Heat discharged from thermal electric generating plants situated along the larger streams in the Great Miami subbasin contribute further to degradation of stream quality.

Flooding is a problem at many locations; upstream watershed areas are in particular need of additional protection.

Land treatment and management and additional irrigation and drainage improvements will be required to develop the full economic potential of the land base.

Additional outdoor recreation facilities are needed in the Hamilton-Middletown-Dayton and Springfield metropolitan areas. Due to the high degree of urbanization in these areas, outdoor recreational demand is high and is projected to increase considerably. To keep pace with this demand, existing areas must be expanded and many new areas developed to provide the opportunity required.

a. Going Program Accomplishment. Summary data for projects in the going program are given in Appendix K, tables 15 through 20. See figure GM-1 for location.

The major flood control works in the Great Miami subbasin are those constructed and maintained by the Miami Conservancy District. The original works, constructed between 1918 and 1922, constituted the first

systems approach to flood control in the Ohio Basin. Developments existing in 1965 consisted of five retarding basins with 841,000 acre-feet of flood storage capacity and 12 local protection projects with 53 miles of levees and 43 miles of channel improvements through urban areas. The retarding basins control 50 percent of the area in the Great Miami subbasin. The District also furnishes flood plain information to local governmental bodies and encourages flood plain zoning in areas adjacent to the Great Miami River.

In addition to the District's control works, two Federal multiple-purpose reservoirs, the Clarence J. Brown Reservoir located in Ohio, and the Brookville Reservoir in Indiana, were under construction. The two will provide a total of about 247,000 acre-feet of storage for control of floods, 21,000 acre-feet for low flow supplementation and 45,000 acre-feet of storage in joint use for both purposes. In addition, 89,000 acre-feet would be provided for water supply in Brookville Reservoir. These reservoirs will control an additional seven percent of the area in the Great Miami subbasin. Two authorized upstream watershed projects in the Great Miami subbasin cover 80 square miles and include 21.4 miles of channel improvement and 11 sites with 5,450 acre-feet of storage capacity for floodwater detention and a small amount for other purposes.

In the Little Miami subbasin, one local protection project was complete and the East Fork and Caesar Creek Reservoirs were in preconstruction planning stage. These two reservoirs will control runoff from about one-third of the area in the Little Miami subbasin. They will provide approximately 359,000 acre-feet of storage for flood control, 146,000 acre-feet of storage for water supply and water quality improvement and 101,000 acre-feet for joint use. There were no authorized watershed projects in the Little Miami subbasin.

The foregoing flood control projects would prevent about 2.6 million dollars in average annual damages with 1965 level of flood plain development. Nearly all of the damages prevented would be in downstream areas.

Ground water within the subbasins has been tapped as the principal source for major municipal and industrial water withdrawals. Ninety-six percent of all municipal supply is furnished from wells. In the interests of future control and improvement of water quality, the Miami Conservancy District recently began studies to determine the most favorable program to meet state and Federal water quality standards.

Commercial navigation is not presently feasible on either the Great Miami or Little Miami Rivers, but both are at times used for pleasure boating, including canoeing on the Little Miami River.

About 1.4 million acres of land had been drained to enhance agricultural production, as inventoried in 1960. Only 3,800 acres received supplemental irrigation.

In 1960 there were seven state parks, six state fish and game areas, and two major local areas with a total land and water area of 21,046 acres for outdoor recreation. The acreage set aside for water oriented recreation pursuits ranked the area near the bottom in relation to other areas in the Ohio Basin, although visitations ranked third highest. Completion of the four Federal reservoirs and developments in authorized watershed projects will increase available land and water substantially and add significantly to recreational opportunity. Even so, it does not appear that the provision of opportunity will keep pace with demand. In 1960, five million recreation days, 1.7 million angler days, and 830,000 hunter days of outdoor recreation, fishing and hunting were recorded in the two subbasins.

b. Future Demand. By 2020, water withdrawals are expected to nearly double amounts withdrawn in 1960, increasing from about 1.2 billion gallons per day to over 2.3 bgd. Water withdrawals for electric power cooling that comprised about 70 percent of total withdrawals in 1960 are estimated to increase only about 40 percent and total about 50 percent of withdrawals in 2020. Municipal and industrial withdrawals are projected to triple, increasing the relative percentage of total withdrawals from 24 percent in 1960 to 41 percent in 2020.

Organic waste loads discharged to the subbasins' streams are expected to increase in the same order as municipal and industrial water withdrawals, about threefold. These waste loads are the residual amounts remaining after removal of 85 percent of the pollution load from waste water entering sewage treatment plants before discharge to streams. Additional streamflow will be required in many areas to provide the assimilation capacity to absorb the increased waste loads within acceptable standards of quality.

About 36 percent of the potential average annual damages with 1965 level of flood plain development would be prevented by projects in the going program for flood control. Residual average annual damages under these conditions would be about 4.6 million dollars. By 2020, unless additional protective works and management actions are taken to prevent them, potential average annual damages are estimated to become nearly 3.6 times this amount with projected conditions of flood plain development.

Additional electric power generation will be required to support the general growth of the economy. There will be additional capacity installed in the Great Miami-Little Miami subbasins, with some of it in hydroelectric power plants to provide peaking capacity for use in conjunction with thermal or nuclear base load plants. However, it is probable that the greater portion of the energy requirements will be imported from neighboring areas.

By 2020, land area that will require treatment and proper management for efficient use is projected to increase over 2.3 million acres. This is approximately 50 percent of the total area in the two subbasins.

The economic potential for agricultural irrigation and agricultural land drainage is second only to the Wabash subbasin; irrigated land area is projected to increase 188,000 acres by 2020 and additional land that can be economically drained, 580,000 acres.

There will be a critical need in the Great Miami-Little Miami subbasins area for additional facilities for recreation and fish and wildlife. The demand for outdoor recreational opportunities is projected to total over 14 times 1960 use by 2020. This demand, in conjunction with increased hunting and fishing pressure, will require full utilization of water and lands affiliated with water resource development.

3. Resource Availability. The ground water development potential of the Great Miami and Little Miami subbasins is one of the best in the entire Ohio River Basin. The glacial outwash deposits in these basins are capable of yielding many times the amount of water presently withdrawn. The best sources of ground water are the sand and gravel deposits in the lower Great Miami and Mad River valleys. High yielding aquifers are also located along the entire course of the Whitewater valley and in the upper Little Miami River valley. Bedrock aquifers and sand and gravel lenses within the glacial drift yield moderate to large supplies in the northern third of the Great Miami subbasin. The central and southern parts of the subbasins outside the Great Miami and Little Miami River valleys lack a good aquifer.

Conservation of surface waters will be required, particularly in areas with serious water quality problems and where ground water availability is insufficient to serve withdrawal demands. Although detailed inventory of reservoir sites has not been undertaken, the terrain indicates there should be a sufficient number of sites to satisfy 2020 storage requirements.

Ten potential reservoirs have been investigated in some detail and considered feasible. Six of the reservoirs are in the Great Miami subbasin; they have a total storage potential of 244,000 acre-feet. The remaining four are in the Little Miami subbasin and have a total storage potential of 414,000 acre-feet. Twenty-three potential upstream watershed projects have been investigated, 17 in the Great Miami subbasin and six in the Little Miami subbasin. These cover 4,067 square miles of the two subbasins and include 152 sites with a total potential storage capacity of 312,000 acre-feet for sediment control, floodwater storage and other uses.

The known hydroelectric power potential feasible of development in the Great Miami-Little Miami subbasins is relatively small. The Public Service Company of Indiana was issued a preliminary permit, effective 1 January 1964, for a three year period to investigate the feasibility of constructing a 240 megawatt pumped storage installation in conjunction with the Brookville Federal multiple-purpose project on the East

Fork Whitewater River. Two undeveloped power sites with a total capacity of 15 megawatts have been identified in the Little Miami River Basin. Future investigations may determine additional sites feasible of development.

4. Assessment of resource Development Requirements. Principal water supply, water quality and flood problem areas, together with reservoirs and upstream watershed projects in the going program of development, and those identified as potential future projects, are shown on the subbasin map, figure GM-1. Summary data for identified potential projects are given in Appendix K, tables 24 through 28. The relationship of problem areas and projects in the going program is shown schematically in figures GM-2 and LM-2. Key data relating to problem areas are given in table GM-2. The schematic diagrams were used for general orientation in analyzing problems and needs and establishing development requirements for streamflow control. An accounting of storage capacity for streamflow control is given in table GM-3. Results of the subbasin assessment to determine the magnitude and costs of resource development required to satisfy projected demands for water and related functions and services are summarized in table GM-4.

a. Requirements to be Furnished by Identified Resource Potential. Analysis of demands for water and related functions and services and of the means whereby these demands can be satisfied indicates that to solve water supply, water quality, and flood problems, development of additional storage capacity for streamflow control will be required; also flood plain management and local protection projects and channel improvements will be required in several locations, either singly or in combination with streamflow regulation, to better cope with flood problems.

The aggregate storage capacity required by 2020 in addition to the amount available in the going program to provide required streamflow control is estimated to be about 1.65 million acre-feet. About 706,000 acre-feet will be required for control of flood flows and about 940,000 acre-feet to provide for low flow requirements. The combined requirement can be met with 1.51 million acre-feet of reservoir space of which 140,000 acre-feet in identified projects would be utilized on a joint basis.

Of the amount of reservoir capacity required for flood control, 573,000 acre-feet would be provided in the 10 identified potential reservoirs. About 126,000 acre-feet or about 40 percent of the total potential storage distributed in upstream watershed projects would be utilized for flood control. In addition to storage control, 707 miles of channel improvements are included in the potential upstream watershed projects to give added protection in rural areas and to agricultural lands. The location of one small local protection project had

been identified; however, no major local protection projects were proposed as of July 1965. In consideration of projected expansion of economic activity and high degree of urbanization, a rigorous flood plain management program will assist in maintaining the effectiveness of existing and proposed protection and prevent future unwise use of flood plain lands. The damage potential may be reduced as much as 15 to 20 percent by timely management actions.

Thirty-seven areas with existing or potential water supply problems have been identified. Fifty percent of these areas have existing or potential water quality problems. In total, there are 26 water quality problem locations. Flows provided by projects in the going program will help to alleviate water supply and water quality problems, particularly in the Great Miami subbasin, but by 1980 or shortly thereafter all areas are predicted to have problems unless steps are taken to alleviate them. About 231,000 acre-feet of the storage capacity required to supplement streamflows during low flow periods can be provided in identified potential reservoirs and upstream watershed projects. This includes the joint use of 140,000 acre-feet of flood control space. Storage provisions are limited to amounts which are beyond the capability of available surface and ground water sources to satisfy demands. It is estimated that additional ground water pumpage will exceed 500 million gallons per day by 2020.

Inclusion of the identified hydroelectric power potential of 255 megawatts installed capacity as an element of water resource development is based on judgment that the installation would be usable by 1980 to meet a portion of the growing Ohio Basin power requirements, and would be desirable if proved to be economically feasible in comparison to alternative sources of power supply.

Total area in potentially feasible upstream watershed projects is about 2.6 million acres. Of this amount, it is estimated that approximately 1.4 million acres of cropland, pasture, and woodland area, of which nearly 90 percent is crop and pasture land, will require treatment and management to enhance land productivity and serve other beneficial purposes. Retardation of runoff, control of erosion, and reduction of sediment transport to streams are important considerations.

It is estimated that outdoor recreational activity equivalent to 13.7 million recreation days can be accommodated at identified potential reservoirs and developments in potential upstream watershed projects provided necessary access and supporting facilities are made available.

b. Remaining Requirements. Storage capacity of 711,000 acre-feet at unidentified sites is required to supplement streamflows during low flow periods to provide quality control and furnish water for withdrawal and use. It includes an amount for water required in areas not identified by specific location of need and an amount required to provide stream regulation in several identified areas of need, but for

which storage developments are not identified. Future detailed investigations may prove reservoir storage to be more costly than alternative measures for the control of water quality. Intensified studies of ground water potential, including artificial recharge and use of this resource for flow supplementation, should be undertaken. Some transfer of water may be required. Water could be furnished from the Ohio River by installation of pipelines and pumping stations.

Storage capacity that can be made available in identified potential projects is sufficient to provide for subbasin flood control requirements and would furnish essentially all of the capacity required for flood stage reduction on the Ohio River.

The extent to which demand for outdoor recreational opportunity can be satisfied at locations other than provided by identified resource developments has not been defined. A portion of the remaining requirement can be met in conjunction with other needed water resource developments in the subbasin. However, it appears that to satisfy recreation demands in the Great Miami-Little Miami area considerable additional development specifically for recreation will be required.

Remaining land treatment and management requirements are associated with the general land base outside potential watershed projects, with the exception that lands to be irrigated or drained may be located in or outside watershed projects. By the year 2020, approximately 894,000 acres of cropland, pasture, and woodland would be subject to treatment and management measures, some of the more common being contour farming of all types, controlled grassland farming, and improved forest management and utilization. These lands are accounted for in the general inventory of requirements but are not identified by specific location.

TABLE GM-1

GREAT MIAMI, LITTLE MIAMI SUBBASINS
DEMAND FOR WATER AND RELATED FUNCTIONS AND SERVICES

	Unit	Base Year Amount	Projected Increase[1] 1980	Projected Increase[1] 2020
Water Withdrawal				
Municipal and Industrial[2]	Million Gallons Per Day	293.6	169.0	669.8
Electric Power Cooling	Million Gallons Per Day	860	0	340
Rural Communities	Million Gallons Per Day	34.4	0.4	20.0
Rural Domestic and Livestock	Million Gallons Per Day	10.49	5.81	12.01
Irrigation[3]	Million Gallons Per Day	1.9	9.5	90.4
Stream Assimilation of Organic Waste Effluent[4]	1,000 Population Equivalents	283.1	152.7	599.1
Flood Damage Prevention[5]	Million Dollars Annually	2.61	7.39	16.59
Waterway Freight Movement[6]	Million Ton-Miles Annually	0	0	0
Hydroelectric Power - Installed Capacity	Megawatts	0	(Assessed on a basin-wide basis)	
Outdoor Recreation	Million Recreation Days	5.0	21.8	65.6
Sport Fishing	Million Angler Days	1.70	0.25[7]	1.30[7]
Hunting	Million Hunter Days	0.83	0.21[7]	0.53[7]
Commercial Fishing			(Assessed on a basin-wide basis)	
Land Treatment and Management	1,000 Acres	51	1,036	2,338
Drainage	1,000 Acres	1,414	442	580
Irrigation (Land Area)	1,000 Acres	3.8	21.4	188.0

NOTES:
(1) Base year amounts plus projected increase equals gross demands.
(2) Mining industry water requirements not included; assessed on a basin-wide basis.
(3) Withdrawal shown is for average year; drought year may be 45 percent higher.
(4) Residual biochemical oxygen demand after 85 percent waste removal by treatment.
(5) The dollar amounts (1980 and 2020) are indices to the magnitude of the problem and the protection measures required to reduce the potential damaging effects of floods.
(6) An index to the canalization and waterway facilities required to accommodate the transport of waterborne freight.
(7) Net requirements.

TABLE GM-2

GREAT MIAMI, LITTLE MIAMI SUBBASINS
PRINCIPAL CONSIDERATIONS IN DETERMINING STORAGE CAPACITY REQUIREMENTS
FOR CONTROL OF STREAMFLOW

A. SUPPLEMENTAL STREAMFLOW REQUIRED AT KEY LOCATIONS TO CONTROL WATER QUALITY (CFS).

Problem Area(1)	Stream	Required Flow(2) 1980	Required Flow(2) 2020	Flow Provided by Going Program	Supplemental Flow Required 1980	Supplemental Flow Required 2020
Great Miami Subbasin						
Sidney, Ohio	Great Miami River	32	55	18	14	37
Piqua-Troy-Tipp City-Vandalia, Ohio	Great Miami River	60	95	32	28	63
Dayton-Middletown-Hamilton, Ohio	Great Miami River	740	1,400	175	565	1,225
Urbana, Ohio	Mad River	25	40	33	0	7
Springfield, Ohio	Mad River	120	160	115	5	45
Greenville, Ohio Covington-West Milton, Ohio	Greenville Creek Stillwater River	25	40	8	17	32
Eaton, Ohio	Sevenmile Creek	15	30	0	15	30
Oxford, Ohio	Fourmile Creek	20	30	0	20	30
Bellefontaine, Ohio	Buckongahelas Creek	20	30	0	20	30
Connersville, Ind	West Fork Whitewater River	35	50	35	0	15
Richmond, Ind	East Fork Whitewater River	50	90	2	48	88
Little Miami Subbasin						
Shawnee Creek & Little Miami River, Ohio		28	45	0	28	45
Beaver Creek & Little Miami River, Ohio		28	45	0	28	45
Kettering, Ohio	Little Beaver Creek	28	45	0	28	45
Lebanon, Ohio	Turtle Creek	14	20	0	14	20
Wilmington, Ohio	Lytles Creek	14	20	0	14	20
Batavia, Ohio	East Fork Little Miami River	40	70	5	35	65

B. WATER REQUIRED TO SATISFY DEMANDS FOR WITHDRAWAL AND USE (IN ADDITION TO THAT PROVIDED IN BASE YEAR) (MGD).

Item	1980	2020
1. Total withdrawal(3)	190	811
2. To be provided by groundwater	129	509
3. Total consumptive use	32	213

C. FLOOD DAMAGE AREAS.

Location	Residual Damages(4) (Millions Dollars)	
1. Upstream areas	2.60	
2. Major urban areas		
No major urban flood damage areas within the scope of this study.		
3. Other flood plain areas	1.96	
4. Total subbasin	4.56	Projected to 7.44 in 1980 and 16.59 in 2020.

NOTES: (1) See figure MI-1 for geographic location of principal problem areas and figure MI-2 for schematic relationship.

(2) Streamflow required to maintain a minimum of 4 parts per million of dissolved oxygen.

(3) Water required to satisfy municipal and industrial, electric power cooling, rural community, rural domestic, and livestock, and irrigation demands.

(4) Estimated average annual damages with the 1965 flood control program completed (1965 constant dollars).

TABLE GM-3

GREAT MIAMI, LITTLE MIAMI SUBBASINS
ACCOUNTING OF STORAGE CAPACITY FOR STREAMFLOW CONTROL
(IN ADDITION TO THAT PROVIDED IN THE GOING PROGRAM)

	Time Period 1980	2020
	Storage (1,000 Ac Ft)	
A. WATER QUALITY CONTROL.		
1. Storage required(1)	343.4	712.0
2. Storage provided in identified potential sites	3.6	3.6
3. Additional storage required	339.8	708.4
B. WATER WITHDRAWALS.		
1. Storage required	53.8	229.6
C. FLOOD CONTROL.		
1. Subbasin and Ohio River control requirement	61.1	706.0
2. Storage provided in identified potential sites	59.3	699.0
a. for solving localized problems	(59.3)	(126.4)
b. effective in controlling both subbasin and Ohio River flows	(0)	(572.6)
3. Additional storage required(2)	1.8	7.0
D. TOTAL STORAGE REQUIREMENT.		
1. Water quality control, water withdrawals, and flood control	458.3	1,647.6
2. Available in identified potential sites(3)	107.6	790.0
3. Joint use storage	11.9	139.8
4. Additional storage required(4)	338.8	717.8

NOTES: (1) Storage capacity required to provide supplemental flows at key urban locations and rural communities in upstream watershed areas.

(2) Remaining Great Miami, Little Miami subbasins share of storage required to reduce the Ohio River Basin Standard Project Flood to the maximum flood stage of record.

(3) See figure GM-1.

(4) Terrain indicates storage sites are potentially available.

TABLE GM-4

GREAT MIAMI, LITTLE MIAMI SUBBASINS
SUMMARY ASSESSMENT OF RESOURCE DEVELOPMENT REQUIREMENTS

Program Elements	Unit	Provided in Going Program	Additional Requirement(1) 1980 Amount	1980 Capital Cost ($1,000)	2020 (Accumulative) Amount	2020 (Accumulative) Capital Cost ($1,000)
PART 1. TO BE FURNISHED BY IDENTIFIED RESOURCE POTENTIAL WITHIN SUBBASIN.						
A. Streamflow Control and In-Stream Use						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	401.9	48.3	6,200	91.0	15,900
2. Control of Flood Flows						
a. reservoir and detention storage	1,000 Ac Ft	612.2	59.3	24,300	699.0	177,700
b. local protection projects	Miles	0	0	0	0	0
c. channel improvement	Miles	22	342	11,200	707	24,100
3. Navigable Waterway						
a. improvement to existing waterway	Miles of Channel	0	-	-	-	-
b. new waterway	Miles of Channel	-	-	-	-	-
c. channel deepening to 12 feet	Miles of Channel	-	-	-	-	-
4. Hydroelectric Power - Installed Capacity	Megawatts	0	255	28,700	(Assessed on a Basin-wide Basis)	
B. Related Programs						
1. Outdoor Recreation(2)(3)	Million Recreation Days	5.0	1.8	6,800	13.7	49,800
2. Watershed Project Land Treatment and Management(4)	1,000 Acres	51	672.1	16,800	1,443.7	36,100
	COSTS - PART 1			94,000		303,600
PART 2. REMAINING REQUIREMENTS.						
A. Streamflow Control and In-Stream Use(5)						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	-	337.0	85,900	710.8	181,300
2. Storage for Control of Flood Flows	1,000 Ac Ft	-	1.8	500	7.0	1,800
3. Hydroelectric Power				(Assessed on a Basin-wide Basis)		
B. Related Programs						
1. Outdoor Recreation(2)(6)	Million Recreation Days	-	20.1	69,900	51.9	180,700
2. Fish and Wildlife						
a. sport fishing(2)(6)	Million Angler Days	1.70	0.25	900	1.30	4,600
b. hunting(2)(6)	Million Hunter Days	0.83	0.21	700	0.53	1,900
c. commercial fishery				(Assessed on a Basin-wide Basis)		
C Land Treatment and Management						
1. Lands Outside Watershed Projects	1,000 Acres	-	363.7	9,100	894.1	22,400
2. Irrigation (Acres to be Irrigated)	1,000 Acres	3.8	22.3	2,000	198.7	18,300
3. Drainage	1,000 Acres	1,414	463.8	65,400	583.1	82,200
	COSTS - PART 2			234,400		493,200
	TOTAL COSTS - (PARTS 1 AND 2)			328,400		796,800

NOTES: (1) Requirement in addition to that provided by going development programs.

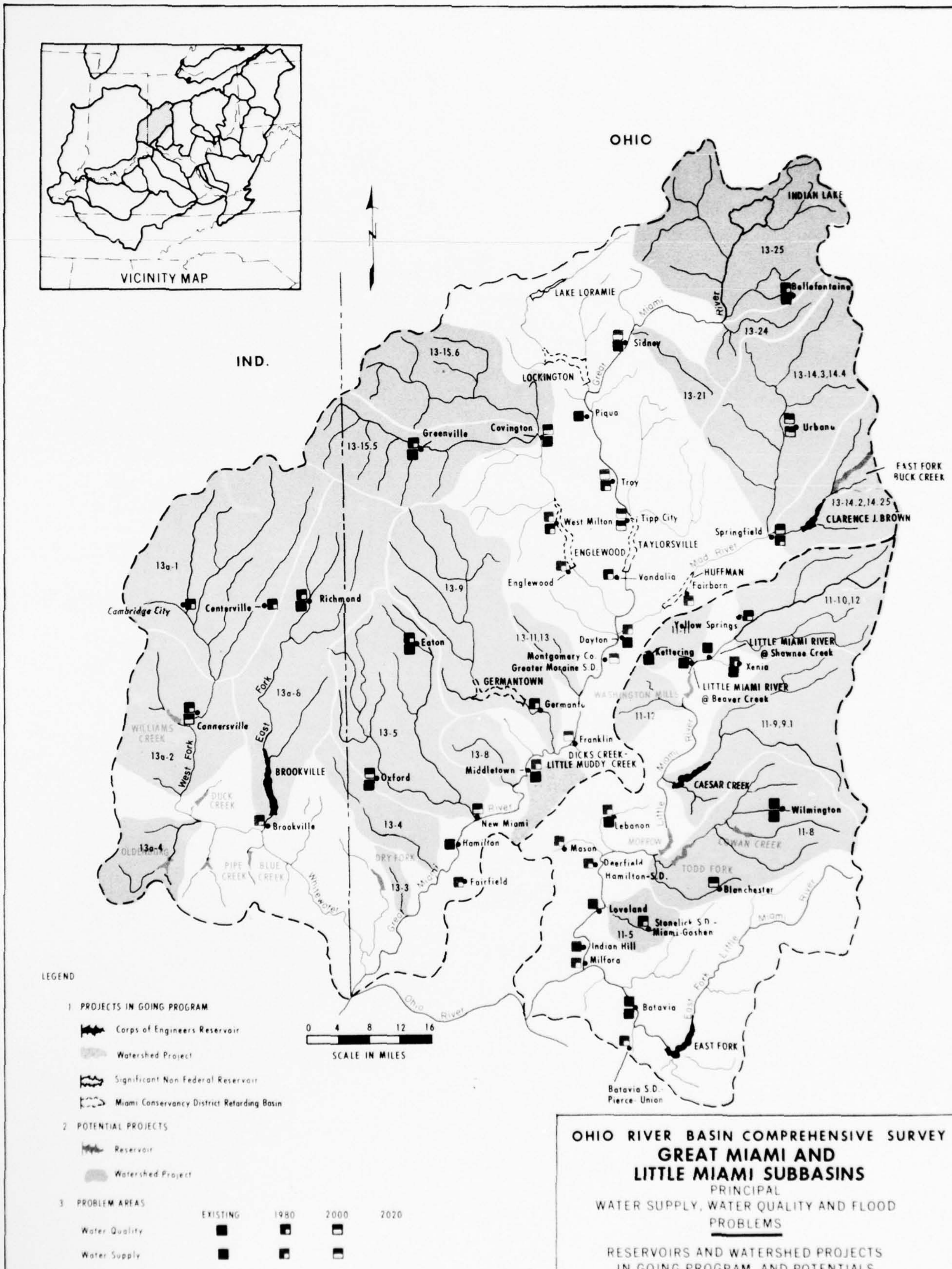
(2) Costs shown are for initial facilities and such measures as may be required to implement the program, and do not include water and related land cost. Base year 1960.

(3) The number of outdoor recreation days shown include some sport fishing and hunting which could not be separately accounted for in available data.

(4) Land area and costs shown are for total land treatment and management requirements in watershed projects and cover both water resource development related and other lands.

(5) Specific sites to provide storage capacity for streamflow control are not identified; however, favorable storage sites are potentially available.

(6) Because of population and resource distributions, remaining subbasin requirements for outdoor recreation, sport fishing and hunting not satisfied by water resource developments may require a trade off with adjacent subbasins or satisfied by other means.



OHIO RIVER BASIN COMPREHENSIVE SURVEY

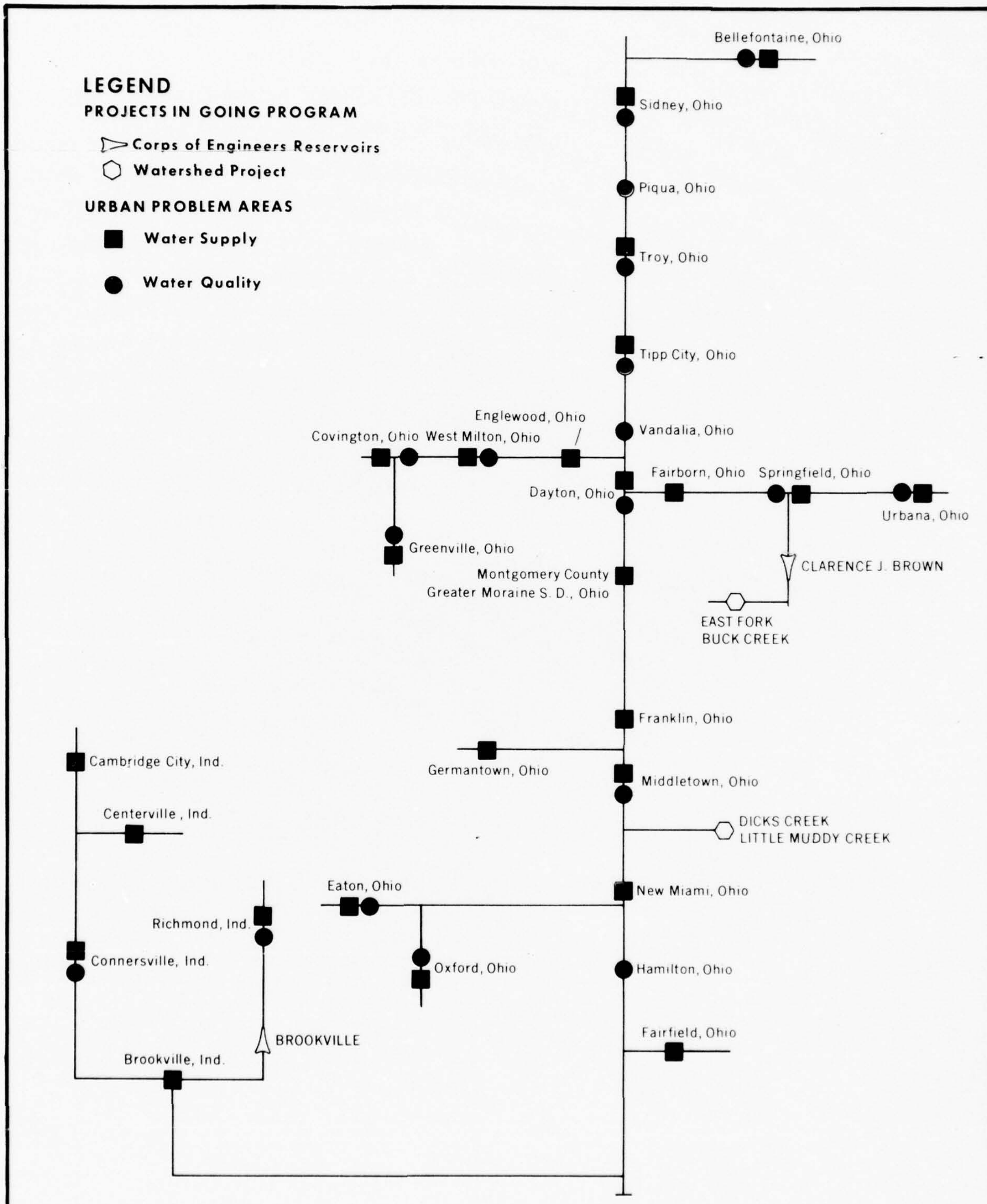
GREAT MIAMI AND LITTLE MIAMI SUBBASINS

PRINCIPAL WATER SUPPLY, WATER QUALITY AND FLOOD PROBLEMS

RESERVOIRS AND WATERSHED PROJECTS IN GOING PROGRAM, AND POTENTIALS

CORPS OF ENGINEERS
APPENDIX K

U.S. ARMY OHIO RIVER DIVISION
FIGURE GM-1

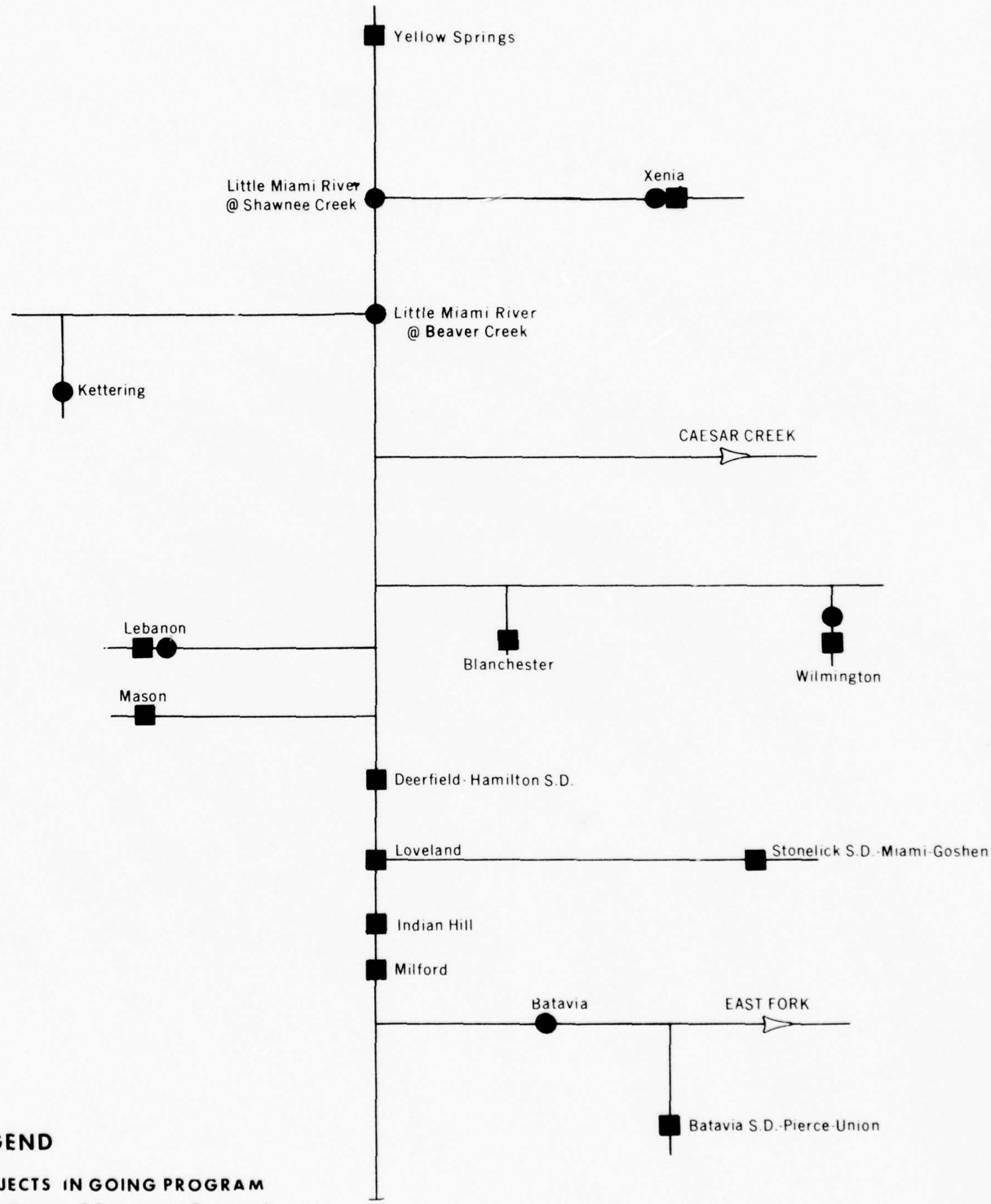


OHIO RIVER BASIN COMPREHENSIVE SURVEY

GREAT MIAMI SUBBASIN
ANALYSIS SCHEMATIC

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE GM-2



LEGEND

PROJECTS IN GOING PROGRAM

Corps of Engineers Reservoir

PROBLEM AREAS

Water Supply

Water Quality

Note: Subbasin is Located in Ohio

OHIO RIVER BASIN COMPREHENSIVE SURVEY

LITTLE MIAMI SUBBASIN ANALYSIS SCHEMATIC

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE LM-2

LICKING, KENTUCKY AND SALT

1. Planning Environment. The Licking, Kentucky and Salt subbasins are situated in the south-central portion of the Ohio Basin. The three subbasins contain 3,760, 6,790 and 2,890 square miles, respectively, totaling over eight percent of the Ohio Basin study area. All three lie entirely within the Commonwealth of Kentucky. The topography varies from the rolling Bluegrass Region to the rugged Appalachian Mountains with much of the land heavily forested.

The subbasins have a history of heavy winter and spring rains and summer thunderstorms with intense rainfall. In contrast, extended droughts, although infrequent, have caused major crop losses and acute water supply shortages. Average annual runoff is greater from the three subbasin area than the average for the Ohio Basin and flooding occurs frequently. Flood waters from these three basins contribute materially to Ohio River flood problems.

The rivers formed important links between wagon trails through the Cumberland Mountains and the Kentucky area during early settlement. Earliest immigrants settled along the Kentucky River in the mid 1700's where the rich soils and bountiful forests and wildlife made conditions ideal for a self-contained economy. Other migrants, using the Ohio River for a transportation route, settled in the area adjacent to the confluence of these rivers with the Ohio.

The Licking-Kentucky-Salt subbasins are treated as a single economic area. This area has about 3.8 percent of the population, 3.5 percent of the labor force and produces 2.7 percent of the industrial output of the Ohio Basin. Although agriculture has been the traditional mainstay of the economy, it is rapidly declining. Agricultural employment has declined from 53 to 21 percent of the total employment during the period 1930 to 1960 and is expected to be surpassed by the increasing manufacturing employment by 1980. The Licking River subbasin has its major industrial development in the extreme lower river. The Kentucky subbasin contains Frankfort, the State capital, and Lexington, a center of commerce and industry, in addition to many small communities. Coal is mined in the upstream Licking and Kentucky subbasins. The Salt River subbasin has no major large cities. A large portion of the area is in Appalachia where many of the residents are unemployed and receive less than adequate income. Projective economic studies indicate that the general economy of the three subbasins will continue to grow, but at a lesser rate than that of the overall Ohio Basin.

2. Demand for Water and Related Functions and Services. Although the area is predominantly rural, there are a considerable number of commercial and industrial communities within the subbasins creating significant demands for flood control, water supply, navigation, recreation and other water resource based facilities. The concentration of population in the industrialized areas create problems of pollution in streams from

municipal and industrial waste during summer and fall periods of low flow. Acid drainage from active and abandoned mines situated in the upper Licking and Kentucky subbasins has further degraded the streams of these subbasins.

In general, present water supplies in the three subbasins are adequate in quantity and, if properly controlled, are sufficient to supply future needs. The improvement of water quality is a major concern. The quality of surface waters and, in some cases ground water, is unsuitable for many uses. Low flow augmentation and control of erosion and mine drainage will be required to provide adequate water quality.

Flooding is a problem in many locations. There are two major damage areas on Licking River, one on Kentucky River and one on North Fork Kentucky River. About two-thirds of the damages are in downstream areas. Erosion control and flood protection are needed in the upstream areas of all subbasins.

The people of the area are currently in need of additional outdoor recreation facilities. If projected future recreational desires are to be satisfied, further sources of water-based opportunity will be needed. Realization of the substantial potential for recreation development within the basin will require the provision of ready access to the resource areas and the construction of adequate facilities.

a. Going Program Accomplishment. Federal, state and local interests have endeavored to keep pace with the more critical development needs. Control through legislative enactments, and research and reclamation efforts have been initiated to solve acid mine drainage and sediment pollution of streams. Strip mine reclamation has been accomplished on about 50 percent of the mined area. Summary data for projects in the going program are given in Appendix K, tables 15 through 21. See figure LK-1 for location.

Buckhorn Reservoir, in the Kentucky Basin, is the only existing Federal multiple-purpose reservoir. It provides a total of 157,700 acre-feet of storage for control of flood runoff from about six percent of the Kentucky subbasin. About twenty-two thousand acre-feet of this is used for a summer conservation pool. Also in the Kentucky subbasin in addition to Buckhorn, the Carr Fork Reservoir under construction, and the Red River, Booneville and Eagle Creek Reservoirs in preconstruction planning would provide control over an additional 19 percent of the drainage area of the Kentucky subbasin and would provide an additional 752,500 acre-feet of storage for flood control. In addition, they would furnish 153,500 acre-feet of storage for quality control and water supply and 174,600 acre-feet of joint storage space from the seasonal flood control pool. Recreational facilities are also being provided.

LICKING, KENTUCKY AND SALT

Cave Run Reservoir under construction in the Licking subbasin will control 22 percent of the drainage area of that subbasin. It will provide storage of 438,500 acre-feet for flood control, 28,300 for low flow supplementation and 47,000 acre-feet for joint use.

There are three authorized watershed projects, one in each of the subbasins. These projects cover 88 square miles. They include 14 structure sites which have a total storage capacity of 2,832 acre-feet and 31 miles of channel improvement. Three Federal local protection projects consisting of floodwalls, levees and a channel cutoff, further control damaging flood flows. The foregoing flood control developments, when complete, will prevent about 3.5 million dollars in flood damages annually, with 1965 levels of flood plain development, leaving a residual of 5.7 million.

Flowing streams within the basin have been tapped as the principal source of major municipal and industrial water supplies. Existing impoundments for water supply, in most cases, have been associated with the provision of small public sources of supply. Ground water sources in the three subbasins are generally limited.

Dix Dam in the Kentucky subbasin is the only hydroelectric generating plant. It is owned by a utility company and has a capacity of 28.3 megawatts.

The lower reach of the Kentucky River was improved for slack water navigation during the late 1800's. The upper reach followed and, since 1917, fourteen locks and dams have provided 255 miles of slack water pools. The structures, however, are obsolete due to small lock size and limiting 6-foot channel depth, but are still being used, primarily for recreation. The capability of the Kentucky River waterway is about 30 million ton-miles annually. The Markland Dam on the Ohio River provides a slack water reach on the Licking River that is navigable for about 15 miles.

Recreation facilities at reservoirs and watershed projects and along natural streams have been provided by Federal and non-Federal interests. Several National Forests, numerous state parks, forests and recreation areas exist in the three subbasins, and recreational tourism provides a significant part of the economy. Stream pollution cleanup efforts have enhanced these programs. Development and management programs have been put into effect to improve land cover and provide facilities for recreation, hunting and fishing throughout the subbasin. Even so, the provision of opportunity for outdoor recreation has not kept pace with demand. In 1960 the three subbasins provided 600,000 recreation days, 1.4 million angler days and 1.3 million hunter days of outdoor recreation, fishing and hunting.

b. Future Demand. Projected net requirements of the expanding economy, which will intensify demand for further use, development and management of water and related land resources, are shown in table LI-1.

It will be noted that water supply withdrawals in 1960 will be about five times as much by 2020, increasing from about 550 million gallons per day to over 4,000 mgd. Sufficient streamflow to assimilate treated wastes within acceptable standards of quality is needed to absorb organic waste loads that are projected to increase six times by 2020. The waste load assimilation needs assessed are the residuals reaching water bodies after secondary treatment removing 85 percent of the BOD.

Although 38 percent of the potential natural monetary damages from flood flows would be prevented by flood control works in the going program, many flood plain areas are unprotected or have insufficient protection. These areas are subject to future economic development due to the limited valley lands in flood-free areas. Additional protection works and management programs will be needed to prevent potential average annual flood damages 2.7 times those with 1965 level development.

Hydroelectric power development in conjunction with water control reservoirs and feasible pumped storage sites where found feasible in comparison to alternate sources of supply can be utilized to supply peak portions of the growing Ohio Basin power loads.

The demand for outdoor recreational opportunities is predicted to increase tremendously from a 1960 use of 600,000 to 53.7 million recreation days by 2020. This demand, in conjunction with hunting and fishing needs, will require full utilization of all water resource and related land potentials.

Operation and ordinary maintenance of navigation facilities on the Kentucky River are presently continuing at minimum levels. Rehabilitation work has been held to what has been considered to be essential to keep the locks in operation and to maintain pool levels above the dams. As a result, many of the lock and dam structures are in poor condition. The remaining useful life of the navigation structures without major replacements is indeterminate. Existing facilities, however, are considered adequate to supply the needs of the private recreational craft which comprise the greatest amount of Kentucky River traffic. Vigorous exploitation of the resources of the Kentucky subbasin could produce net requirements of 180 million ton-miles annually on the waterway. However, competitive disadvantage with other producing areas due to remoteness from markets, and higher production costs, does not presently indicate transportation savings adequate to justify the cost of the required waterway improvement.

3. Resources Availability. The surface water resource development potential of the Licking-Kentucky-Salt subbasins is one of the best in the Ohio Basin. Annual surface runoff is high although seasonal variations in flow are great. The rugged topography and lack of major urban or industrial developments in the tributary valley areas provide favorable opportunities to develop stream regulation reservoirs. Nine upstream watershed projects and reservoir sites in the Licking subbasin, including the authorized Falmouth site, have been investigated in some detail. In the Kentucky subbasin eleven additional potential reservoir sites and 22 upstream watershed projects have been identified. In the Salt subbasin, there are four identified potential reservoir sites, one of which is the recently authorized Taylorsville Reservoir and ten potential watershed projects. The total of forty-one potential watershed projects, which have been identified in the three subbasins, cover 4,011 square miles and include 201 structure sites. Total identified storage potential in the three subbasins, over and above that in the going program, is estimated at over 5 million acre-feet.

Because of the entrenched streams, additional pumped storage hydropower projects with high heads may be found that are feasible of development. There are at least eight identified locations where hydroelectric plants may be feasible; two of these are pumped storage projects.

Ground water in large supplies is available only in the extreme southeastern headwater area. Moderate supplies are available from sandstone in the adjacent coalfield region, from limestone in the inner Bluegrass Region near Lexington, and from sand and gravel along the lower reaches of the Licking, Kentucky and Salt Rivers. Elsewhere, ground water yields are adequate only for small domestic supplies; consequently, in most of the area, streams are the only source of large water supplies.

Extensive scenic and wooded areas are available for outdoor recreation development and wildlife management.

4. Assessment of Resource Development Requirements. Principal water supply, water quality and flood problem areas, together with reservoirs and upstream watershed projects in the going program of development, and those identified as potential future projects, are shown on the subbasin map, figure LK-1. Summary data for identified potential projects are given in Appendix K, tables 24 through 28. The relationship of problem areas and projects in the going program is shown schematically in figures LI-2, KY-2 and SA-2. Key data relating to problem areas are given in table LI-2. The schematic diagrams were used for general orientation in analyzing problems and needs and establishing development requirements for streamflow control. An accounting of storage capacity for streamflow control is given in table LI-3. Results of the subbasin assessment to determine the magnitude and costs of resource development required to satisfy projected demands for water and related functions and services are summarized in table LI-4.

a. Requirements to be Furnished by Identified Resource Potential. Analysis of demands for water and related functions and services and of the means whereby these demands can be satisfied indicates that to solve water supply, water quality, and flood problems, development of additional storage capacity for streamflow control will be required; also, further local protection projects and channel improvements will be required in several locations, either singly or in combination with streamflow regulation, to better cope with flood problems.

The aggregate storage capacity required to provide streamflow control is estimated to be 4.1 million acre-feet in addition to the amount that will be made available upon completion of the going program. About 3.6 million acre-feet will be required for control of flood flows and 451,000 acre-feet to provide for low flow requirements. The combined requirement can be met with 3.9 million acre-feet of reservoir space, of which 177,000 acre-feet would be utilized on a joint use basis.

Of the amount of storage space required for flood control, 3.3 million acre-feet of reservoir capacity, including 440,000 acre-feet associated with upstream watershed projects, can be provided by the identified resource potential. In addition to control by storage, 31 miles of channel improvements in potential upstream watershed projects and major local protection works at two localities have been identified. An aggressive flood plain management program can assist in maintaining the high percentage of damage reduction that will be afforded by proposed protection.

By 2020, 451,000 acre-feet of storage capacity will be required to provide sufficient streamflow at 41 locations with major water supply or water quality problems. Storage capacity in identified potential reservoirs is sufficient to satisfy this requirement. Waste treatment, in addition to flow supplementation, will undoubtedly be required to handle some of the complex industrial wastes in the lower reaches of the Licking, Kentucky and Salt Rivers. Storage capacity provisions for streamflow supplementation are limited to amounts required to satisfy demands beyond the capability of available surface flows and ground water sources. The ground water potential is considered adequate to provide 20 million gallons per day in addition to pumpage inventoried in 1960 toward satisfying 2020 water requirements.

The identified hydroelectric power potential of 931 megawatts installed capacity would be useable before 1980 to meet a portion of the growing Ohio Basin power requirements. Inclusion of the power potential as an element of water resource development is based on judgment that the installation will prove to be desirable and economically feasible in comparison to alternative sources of power supply.

Total area in potentially feasible upstream watershed projects is about 2.6 million acres. Of this amount, it is estimated that approximately 1.5 million acres of cropland, pasture, and woodland will require treatment and management to enhance land productivity and serve other beneficial purposes. Retardation of runoff, control of erosion, and reduction of sediment transport to streams are important considerations.

The availability of streams with improved water quality, reservoirs, impoundments, and other developments would provide potential opportunities for 34 million outdoor recreation days annually if access and facilities are made available.

b. Remaining Requirements. Storage capacity that can be made available in identified potential projects is sufficient to provide for subbasin flood control requirements and would also furnish a portion of the capacity required for flood stage reduction on the Ohio River. The 390,000 acre-feet for which additional development will be required is the remaining amount needed in the Licking, Kentucky and Salt subbasins to assist in regulating the Ohio River Standard Project Flood.

The extent to which demand for outdoor recreation, hunting, and fishing opportunity can be satisfied beyond that provided by identified developments has not been assessed. A portion of the remaining requirement can be met in conjunction with needed water resource developments in the subbasin. The rest will likely have to be provided by single-purpose recreation lakes, State and local parks, and private developments.

Remaining land treatment and management requirements are associated with the general land base outside watershed projects, with the exception that lands to be irrigated or drained may be located in or outside watershed projects. By the year 2020, approximately 2.5 million acres of cropland, pasture, and woodland would be subject to treatment and management measures, some of the more common being contour farming of all types, controlled grassland farming, and improved forest management and utilization. These lands are accounted for in the general inventory of requirements but are not identified by specific location.

TABLE LI-1

LICKING, KENTUCKY, SALT SUBBASINS
DEMAND FOR WATER AND RELATED FUNCTIONS AND SERVICES

	Unit	Base Year Amount	Projected Increase[1] 1980	Projected Increase[1] 2020
Water Withdrawal				
Municipal and Industrial[2]	Million Gallons Per Day	43.4	22.6	195.6
Electric Power Cooling	Million Gallons Per Day	467	321	3,213
Rural Communities	Million Gallons Per Day	20.6	17.0	35.5
Rural Domestic and Livestock	Million Gallons Per Day	13.31	0	2.08
Irrigation[3]	Million Gallons Per Day	4.6	10.1	25.8
Stream Assimilation of Organic Waste Effluent[4]	1,000 Population Equivalents	106.9	82.8	558.4
Flood Damage Prevention[5]	Million Dollars Annually	3.47	7.91	15.55
Waterway Freight Movement[6]	Million Ton-Miles Annually	30	30	180
Hydroelectric Power - Installed Capacity	Megawatts	28.3	(Assessed on a basin-wide basis)	
Outdoor Recreation	Million Recreation Days	0.6	20.0	53.7
Sport Fishing	Million Angler Days	1.40	0.13[7]	0.93[7]
Hunting	Million Hunter Days	1.30	0.33[7]	0.62[7]
Commercial Fishing			(Assessed on a basin-wide basis)	
Land Treatment and Management	1,000 Acres	56	1,401	3,953
Drainage	1,000 Acres	32	40	47
Irrigation (Land Area)	1,000 Acres	8.8	23.5	54.7

NOTES: (1) Base year amounts plus projected increase equals gross demands.

(2) Mining industry water requirements not included; assessed on a basin-wide basis.

(3) Withdrawal shown is for average year; drought year may be 45 percent higher.

(4) Residual biochemical oxygen demand after 85 percent waste removal by treatment.

(5) The dollar amounts (1980 and 2020) are indices to the magnitude of the problem and the protection measures required to reduce the potential damaging effects of floods.

(6) An index to the canalization and waterway facilities required to accommodate the transport of waterborne freight.

(7) Net requirements.

TABLE LI-2

LICKING, KENTUCKY, SALT SUBBASINS
PRINCIPAL CONSIDERATIONS IN DETERMINING STORAGE CAPACITY REQUIREMENTS
FOR CONTROL OF STREAMFLOW

A. SUPPLEMENTAL STREAMFLOW REQUIRED AT KEY LOCATIONS TO CONTROL WATER QUALITY (CFS).

Problem Area (1)	Stream	Required Flow (2) 1980	Required Flow (2) 2020	Flow Provided by Going Program	Supplemental Flow Required 1980	Supplemental Flow Required 2020
Licking Subbasin						
Newport	Licking River	90	175	11	79	164
Paris	Stoner Creek	22	30	0	22	30
Winchester	Strodes Creek	15	40	0	15	40
Mt. Sterling	Hinkston Creek	8	15	0	8	15
Cynthiana	South Fork Licking River	35	40	1	34	39
Morehead	Triplett Creek	8	15	0	8	15
Kentucky Subbasin						
Lexington	Kentucky River	410	700	33	377	667
Georgetown	North Fork Elkhorn Creek	12	25	0	12	25
Hazard	North Fork Kentucky River	8	25	2	6	23
Jackson	North Fork Kentucky River	8	25	2	6	23
Richmond	Otter Creek	15	45	0	15	45
Owenton	Eagle Creek	4	8	0	4	8
Danville	Clarks Run	14	40	0	14	40
Berea	Silver Creek	8	20	0	8	20
Versailles	Glenn's Creek	11	25	0	11	25
Wilmore	Jessamine Creek	7	16	0	7	16
Nicholasville	Jessamine Creek	7	16	0	7	16
Lancaster	White Oak Creek	6	12	0	6	12
Stanford	Logan Creek	6	12	0	6	12
Salt Subbasin						
Harrodsburg	Salt River	11	30	0	11	30
Shepherdsville	Salt River	74	240	0	74	240
Lawrenceburg	Hammonds Creek	9	28	0	9	28
Shelbyville	Clear Creek	9	28	0	9	28
Lebanon	Hardin Creek	9	28	0	9	28
Springfield	Road Run Creek	5	15	0	5	15
Bardstown	Beech Fork	43	110	1	42	109
New Haven	Rolling Fork	7	17	0	7	17
Jeffersontown	Floyds Fork	10	15	0	10	15

B. WATER REQUIRED TO SATISFY DEMANDS FOR WITHDRAWAL AND USE (IN ADDITION TO THAT PROVIDED IN BASE YEAR) (MGD).

Item	1980	2020
1. Total withdrawal (3)	371	3,472
2. To be provided by groundwater	2	20
3. Total consumptive use	36	147

C. FLOOD DAMAGE AREAS.

Location	Residual Damages (4) (Millions Dollars)	
1. Upstream areas	1.66	
2. Major urban areas (1)	0.64	
Salyersville, Licking River Falmouth, Licking River Frankfort, Kentucky River Hazard, North Fork Kentucky River		
3. Other flood plain areas	3.41	
4. Total subbasin	5.71	Projected to 7.91 in 1980 and 15.5 in 2020.

NOTES: (1) See figure LI-1 for geographic location of principal problem areas and figure LI-2 for schematic relationship.

(2) Streamflow required to maintain a minimum of 4 parts per million of dissolved oxygen.

(3) Water required to satisfy municipal and industrial, electric power cooling, rural community, rural domestic and livestock, and irrigation demands.

(4) Estimated average annual damages with the 1965 flood control program completed (1965 constant dollars).

TABLE LI-3

LICKING, KENTUCKY, SALT SUBBASINS
ACCOUNTING OF STORAGE CAPACITY FOR STREAMFLOW CONTROL
(IN ADDITION TO THAT PROVIDED IN THE GOING PROGRAM)

	Time Period	
	1980	2020
	Storage (1,000 Ac Ft)	
A. WATER QUALITY CONTROL.		
1. Storage required(1)	163.3	393.8
2. Storage provided in identified potential sites	65.4	216.9
3. Additional storage required	97.9	176.9
B. WATER WITHDRAWALS.		
1. Storage required	40.2	57.1
C. FLOOD CONTROL.		
1. Subbasin and Ohio River control requirement	1,805.4	3,647.4
2. Storage provided in identified potential sites	1,707.9	3,257.4
a. for solving localized problems	(170.5)	(439.8)
b. effective in controlling both subbasin and Ohio River flows	(1,537.4)	(2,817.6)
3. Additional storage required(2)	97.5	390.0
D. TOTAL STORAGE REQUIREMENT.		
1. Water quality control, water withdrawals, and flood control	2,008.9	4,098.3
2. Available in identified potential sites(3)	1,813.5	3,531.4
3. Joint use storage	97.9	176.9
4. Additional storage required(4)	97.5	390.0

NOTES: (1) Storage capacity required to provide supplemental flows at key urban locations and rural communities in upstream watershed areas.

(2) Remaining Licking, Kentucky, Salt subbasins share of storage required to reduce the Ohio River Basin Standard Project Flood to the maximum flood stage of record.

(3) See figure LI-1.

(4) Terrain indicates storage sites are potentially available.

TABLE LI-4

LICKING, KENTUCKY, SALT SUBBASINS
SUMMARY ASSESSMENT OF RESOURCE DEVELOPMENT REQUIREMENTS

Program Elements	Unit	Provided in Going Program	Additional Requirement(1) 1980 Amount	1980 Capital Cost ($1,000)	2020 (Accumulative) Amount	2020 (Accumulative) Capital Cost ($1,000)
PART 1. TO BE FURNISHED BY IDENTIFIED RESOURCE POTENTIAL WITHIN SUBBASIN.						
A. Streamflow Control and In-Stream Use						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	395.6	105.6	19,200	274.0	59,900
2. Control of Flood Flows						
a. reservoir and detention storage	1,000 Ac Ft	1,351.4	1,707.9	407,200	3,257.4	829,000
b. local protection projects	Miles	8.8	1.0	2,800	(2)	3,400
c. channel improvement	Miles	31	47	1,700	116	4,300
3. Navigable Waterway						
a. improvement to existing waterway	Miles of Channel	259	0	0	0	0
b. new waterway	Miles of Channel	-	-	-	-	-
c. channel deepening to 12 feet	Miles of Channel	-	-	-	-	-
4. Hydroelectric Power - Installed Capacity	Megawatts	28.3	931	104,700	(Assessed on a Basin-wide Basis)	
B. Related Programs						
1. Outdoor Recreation(3)(4)	Million Recreation Days	0.6	11.5	39,300	34.3	115,600
2. Watershed Project Land Treatment and Management(5)	1,000 Acres	56	586.1	16,200	1,491.0	38,900
	COSTS - PART 1			591,100		1,051,100
PART 2. REMAINING REQUIREMENTS.						
A. Streamflow Control and In-Stream Use(6)						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	-	0	0	0	0
2. Storage for Control of Flood Flows	1,000 Ac Ft	-	97.5	24,900	390.0	99,500
3. Hydroelectric Power				(Assessed on a Basin-wide Basis)		
B. Related Programs						
1. Outdoor Recreation(3)(7)	Million Recreation Days	-	8.5	28,300	20.0	56,300
2. Fish and Wildlife						
a. sport fishing(3)(7)	Million Angler Days	1.40	0.13	500	0.93	3,300
b. hunting(3)(7)	Million Hunter Days	1.30	0.33	1,200	0.62	2,200
c. commercial fishery				(Assessed on a Basin-wide Basis)		
C. Land Treatment and Management						
1. Lands Outside Watershed Projects	1,000 Acres	-	814.5	20,400	2,462.2	61,500
2. Irrigation (Acres to be Irrigated)	1,000 Acres	8.8	23.9	2,200	58.6	5,400
3. Drainage	1,000 Acres	32	44.2	7,800	55.1	9,700
	COSTS - PART 2			85,300		247,900
	TOTAL COSTS - (PARTS 1 AND 2)			676,400		1,299,000

NOTES:

(1) Requirement in addition to that provided by going development programs.

(2) Project dimensions not defined at this time.

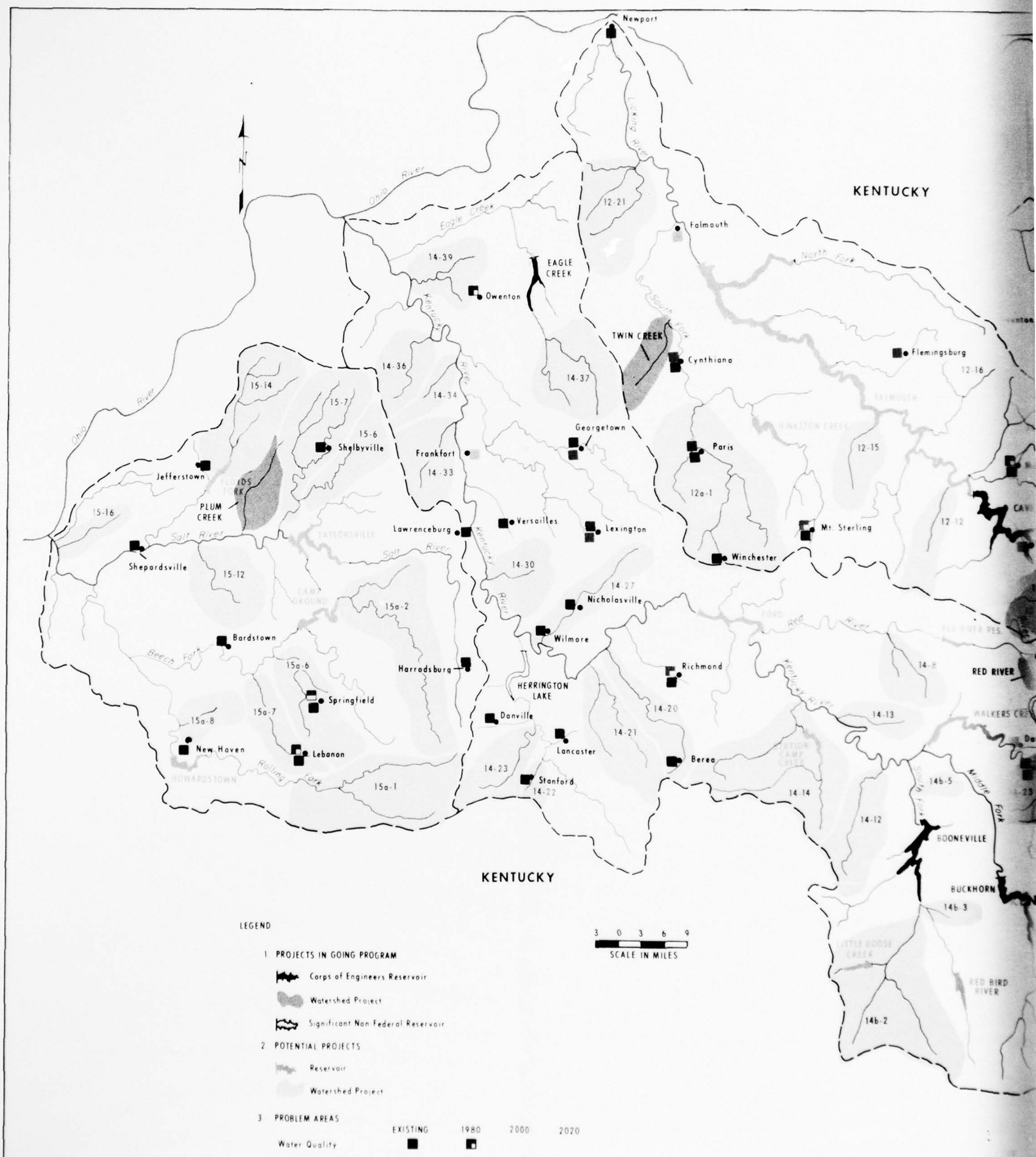
(3) Costs shown are for initial facilities and such measures as may be required to implement the program, and do not include water and related land cost. Base year 1960.

(4) The number of outdoor recreation days shown include some sport fishing and hunting which could not be separately accounted for in available data.

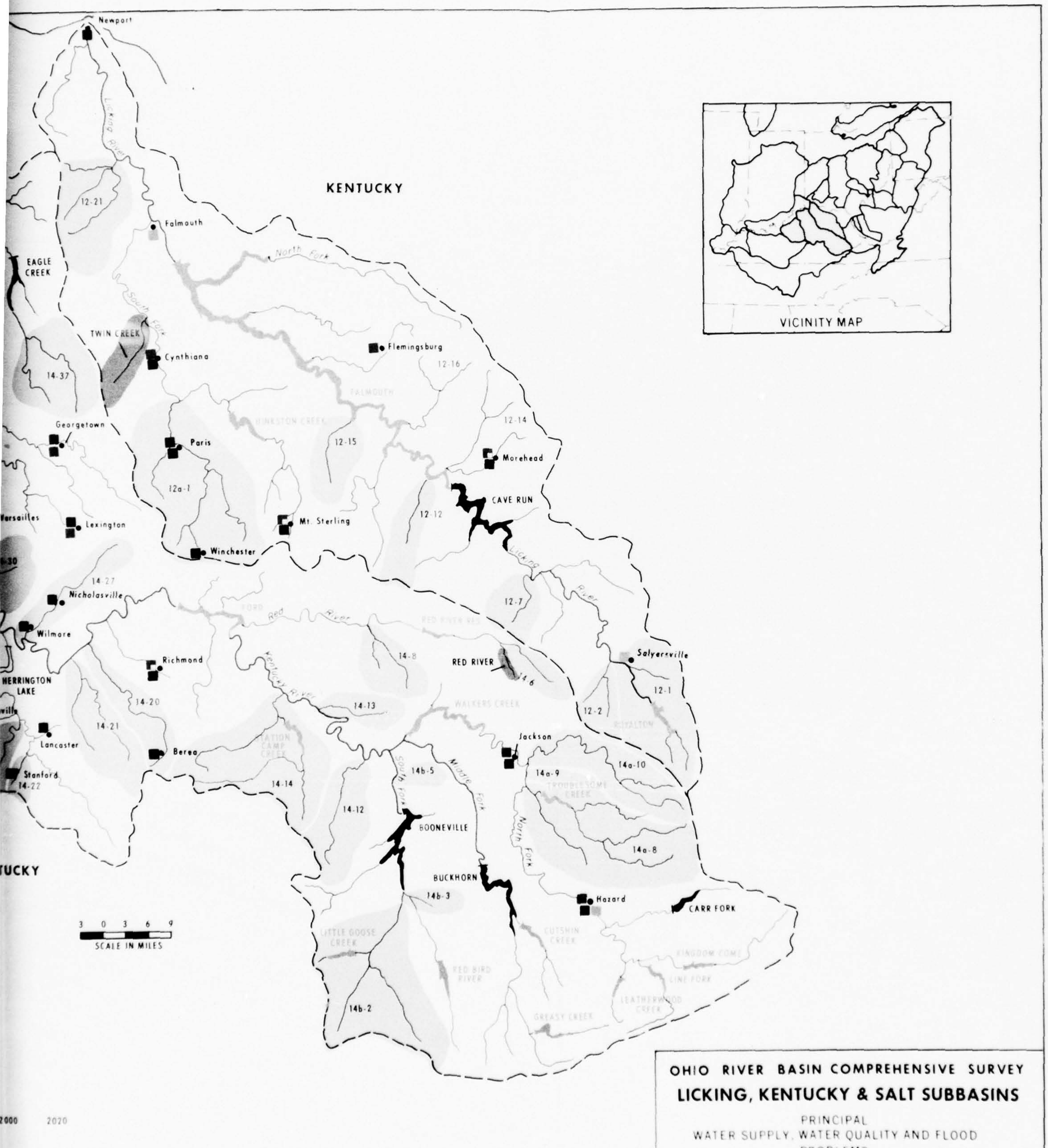
(5) Land area and costs shown are for total land treatment and management requirements in watershed projects and cover both water resource development related and other lands.

(6) Specific sites to provide storage capacity for streamflow control are not identified; however, favorable storage sites are potentially available.

(7) Because of population and resource distributions, remaining subbasin requirements for outdoor recreation, sport fishing and hunting not satisfied by water resource developments may require a trade off with adjacent subbasins or satisfied by other means.



KENTUCKY
Newport
Ohio River
Licking River
Eagle Creek
EAGLE CREEK
12-21
Falmouth
North Fork
South Fork
14-39
Owenton
Kentucky River
TWIN CREEK
Cynthiana
Flemingsburg
12-16
14-36
14-34
14-37
15-14
15-7
15-6
Shelbyville
Frankfort
Georgetown
Paris
12-15
Jefferstown
FLOYDS FORK
PLUM CREEK
14-33
12a-1
15-16
Salt River
Versailles
Lexington
Mt. Sterling
12-12
Lawrenceburg
TAYLORSVILLE
Shepardsville
15-12
Winchester
14-30
CAMP GROUND
14-27
15a-2
Nicholasville
Red River
RED RIVER RES.
Bardstown
Beech Fork
Wilmore
15a-6
Harrodsburg
Richmond
14-8
RED RIVER
HERRINGTON LAKE
Springfield
15a-8
15a-7
Danville
14-20
14-13
WALKERS CREEK
New Haven
Lebanon
Lancaster
14-21
HOWARDSTOWN
Rolling Fork
14-23
Berea
STATON CAMP CREEK
15a-1
Stanford
14-22
14-14
14-12
14b-5
Middle Fork
BOONEVILLE
BUCKHORN
14b-3
KENTUCKY
LEGEND
1 PROJECTS IN GOING PROGRAM
Corps of Engineers Reservoir
Watershed Project
Significant Non-Federal Reservoir
2 POTENTIAL PROJECTS
Reservoir
Watershed Project
3 PROBLEM AREAS
EXISTING
1980
2000
2020
Water Quality
Water Supply
Major Flood Damage
3 0 3 6 9
SCALE IN MILES
LITTLE GOOSE CREEK
RED BIRD RIVER
14b-2



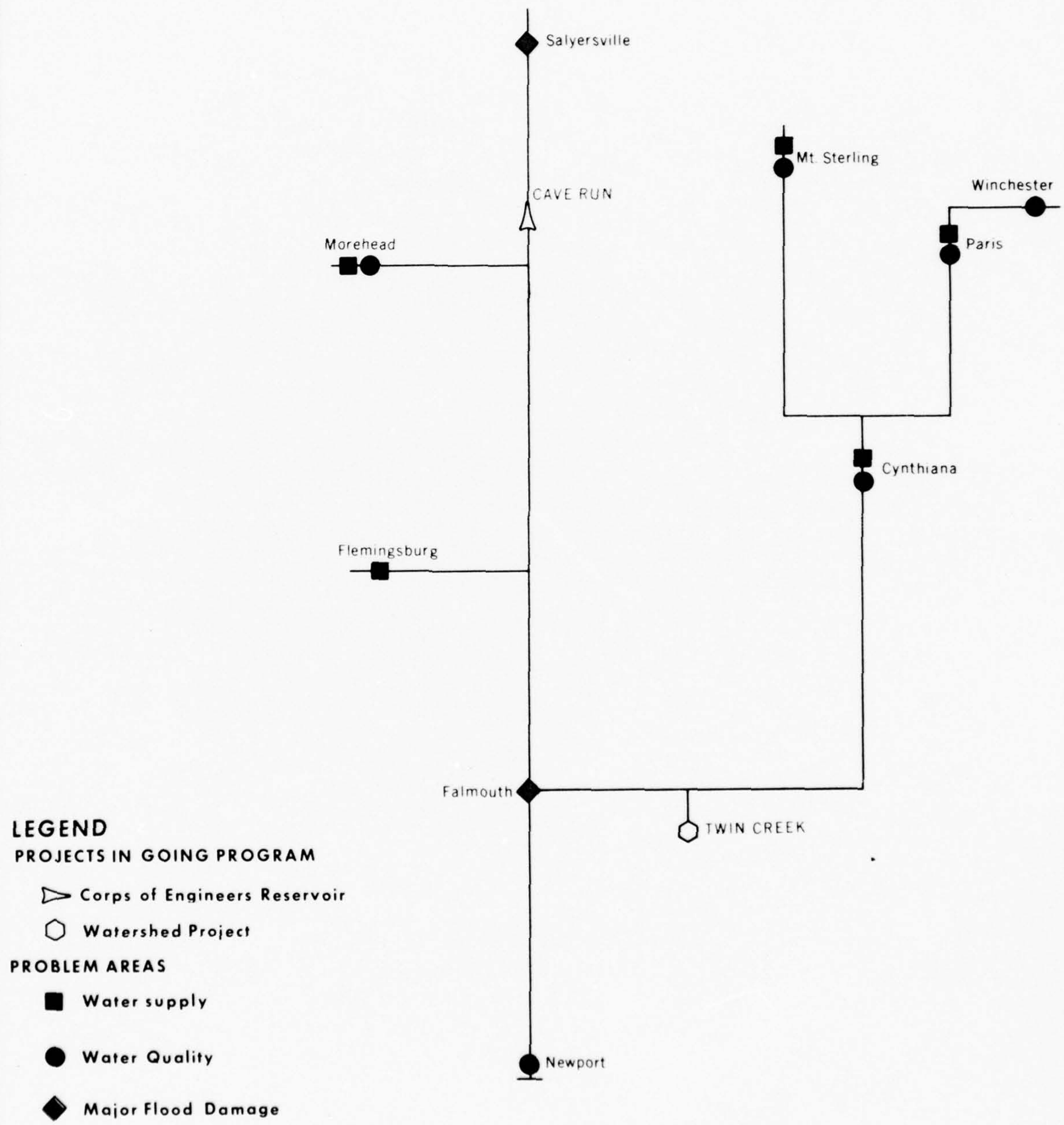
OHIO RIVER BASIN COMPREHENSIVE SURVEY

LICKING, KENTUCKY & SALT SUBBASINS

PRINCIPAL
WATER SUPPLY, WATER QUALITY AND FLOOD
PROBLEMS

RESERVOIRS AND WATERSHED PROJECTS
IN GOING PROGRAM, AND POTENTIALS

CORPS OF ENGINEERS — U.S. ARMY OHIO RIVER DIVISION
APPENDIX K — FIGURE LK-1



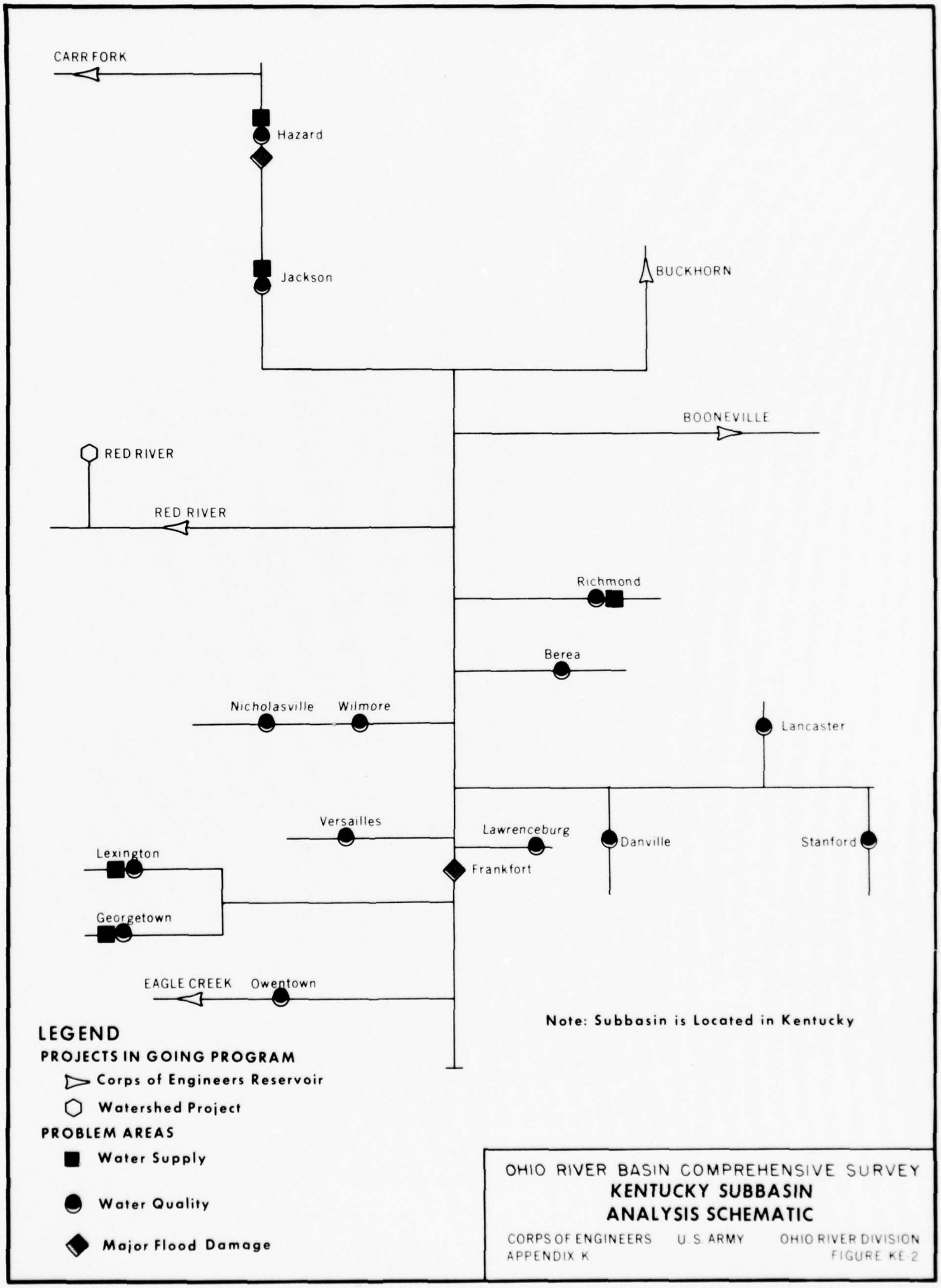
Note: Subbasin is Located in Kentucky

OHIO RIVER BASIN COMPREHENSIVE SURVEY

LICKING SUBBASIN ANALYSIS SCHEMATIC

CORPS OF ENGINEERS U. S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE LI-2

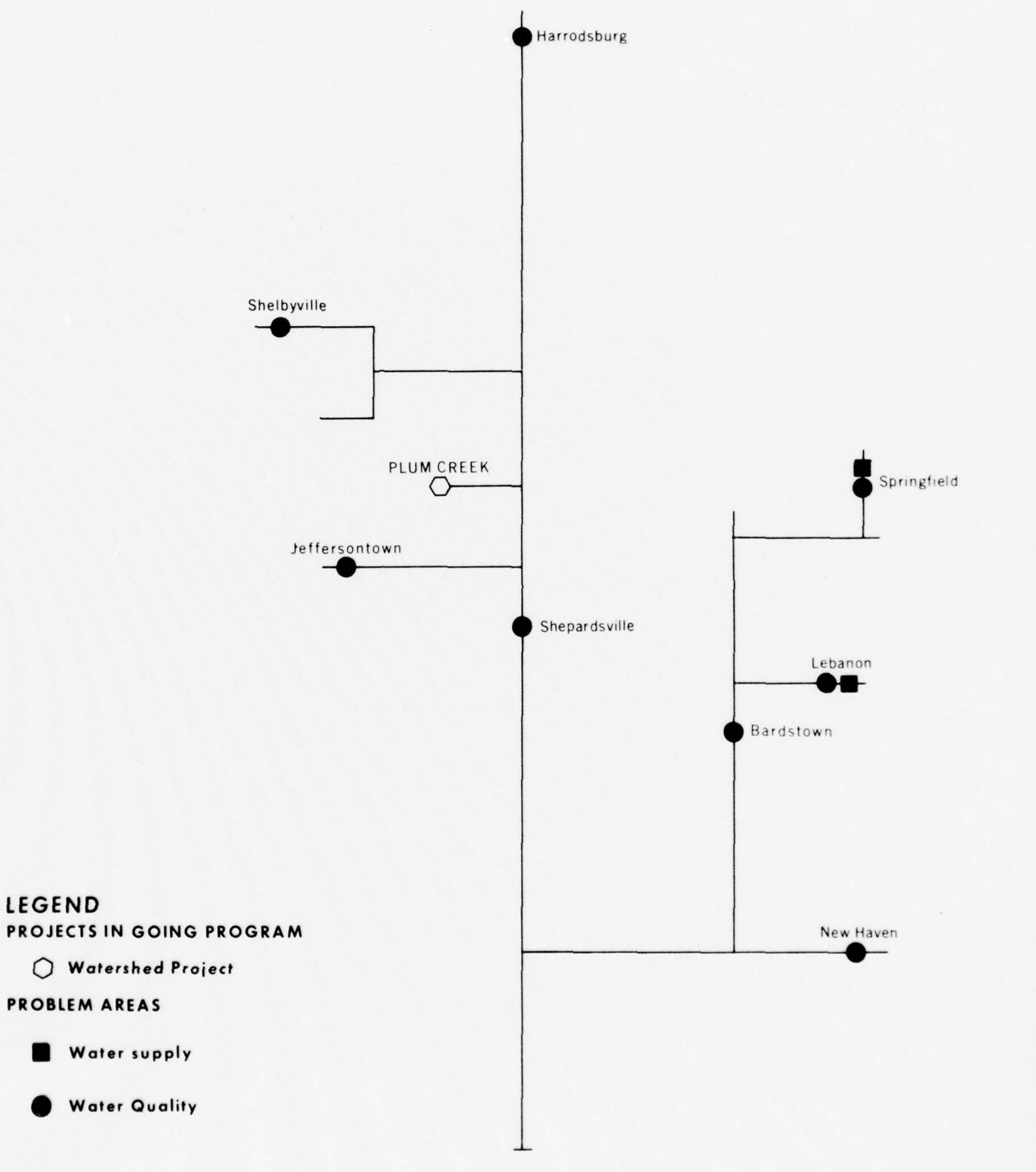


OHIO RIVER BASIN COMPREHENSIVE SURVEY

KENTUCKY SUBBASIN ANALYSIS SCHEMATIC

CORPS OF ENGINEERS U. S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE KE-2



Note: Subbasin is Located in Kentucky

OHIO RIVER BASIN COMPREHENSIVE SURVEY

SALT SUBBASIN

ANALYSIS SCHEMATIC

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE SA-2

GREEN

1. Planning Environment. The Green River subbasin, situated in the southwestern portion of the Ohio Basin, has a general east-west alignment. The subbasin contains 9,230 square miles, or nearly six percent of the Ohio Basin study area, comprising all or part of 28 counties in west-central Kentucky and a small part of three counties in northern Tennessee. The topography varies from the rugged hilly terrain in the eastern part of the subbasin, to the deep valleys and cavern areas of the central section, and the swampy and wide flood plain area of the western or downstream section. The growing season is one of the longest in the Ohio Basin.

The subbasin has a history of recurring heavy rains from widespread storms and also summer thunderstorms with intense rainfall. Runoff has been greater than the average for the Ohio Basin, and flooding occurs frequently. In contrast, extended droughts, although infrequent, have caused major crop losses and acute water shortages.

The Green subbasin has about two percent of the population, 2.1 percent of the labor force and produces 1.5 percent of the Ohio Basin's industrial output. Bowling Green with a population of 28,000 people and Madisonville with 13,000 were the two largest cities in 1960. Agriculture has historically held a dominant position in the area's economy. In 1960, nearly 27 percent of the labor force was engaged in agrarian pursuits. The subbasin contains large commercial coal deposits and a significant portion of the economy is dependent on mining. Ten percent of the strip mining of coal in the Ohio Basin takes place in the Green subbasin. Major industrial centers have not developed and only about 25 percent of the population is presently considered urban. However, by 2020, the urban population is expected to increase to over 50 percent of the total population. Projective economic studies indicate that, although overall industrial growth will be less, manufacturing in the Green subbasin will grow at a greater rate than for the overall Ohio Basin. Largest output is expected in machinery and apparel products.

2. Demand for Water and Related Functions and Services. In general, annual runoff is adequate in quantity and, if properly controlled, sufficient to fill future needs. The natural quality of surface and ground waters is generally good. However, acid drainage from active and abandoned mines causes problems in localized areas. Strip mine operations result in land management and water pollution problems and oil field waste and brines have caused problems in the past, though they seem to be fairly well under control now. The major pollutant in the subbasin is organic waste effluent from the sewer outfalls of cities and communities, mostly in areas tributary to the Green River. The disposal of waste heat from thermal electric power plants is a problem on the lower reach of the Green River.

GREEN

Flooding in the Green River subbasin occurs every year and often several times a year. Medium and high stage floods usually occur in the winter and spring months, inundating vast areas of tillable lands, and remain above flood stage for prolonged periods.

The mining industry with large reserves of coal and other minerals in the subbasin depend on the availability of low-cost transportation for marketing these resources. Coal mining in the subbasin is interrelated with electric power generation, both in and outside the area, and demand for transport of other bulk commodities is increasing. Further development to eliminate the obsolete portion of the Green-Barren navigation system will be essential to meet increased demands for waterborne transport of coal, grain, rock asphalt, crushed limestone, sand and petroleum.

Recreation demand within the Green subbasin is one of the lowest of the Ohio subbasins, primarily because of the relatively small population and distance from metropolitan areas. The substantial potential for recreation development within the subbasin is sufficient to satisfy internal demands and could help satisfy demand from population centers outside the Green subbasin.

a. Going Program Accomplishment. Federal, state and local interests have endeavored to keep pace with development required to solve critical problems and provide for most urgent needs. Steps have been taken toward solving flood problems. Efforts have been initiated to solve mine drainage problems and control sediment pollution of streams. Fifty percent of the strip mined land has been rehabilitated. Improvements in the lower Green River navigation system have been effective in the development of the coal mining industry in the subbasin. Efforts have been made to provide for outdoor recreation, sport fishing and hunting demands; programs for land management and fish and wildlife preservation have been in effect for some time. Summary data for projects in the going program are given in Appendix K, tables 15 through 20. See figure GR-1 for location.

There are three existing Federal multiple-purpose reservoirs in the subbasin. Together with the Green River Reservoir, under construction in 1965, they will provide slightly more than two million acre-feet of storage capacity for control of floods, 227,000 acre-feet of storage for low flow supplementation, and 522,000 acre-feet of storage in joint use for both purposes. These reservoirs control about 30 percent of the subbasin area. There are twelve authorized watershed projects covering 1,293 square miles to provide protection in upstream areas. The projects include 89 detention structures with a total capacity of a little less than 105,000 acre-feet for sediment control, floodwater storage and other uses, and 206 miles of channel improvement. In addition, one major and two minor channel improvement local protection projects

further control damaging flood flows. The foregoing developments would prevent $2.81 million, or about 40 percent, of the potential average annual damages with 1965 level of flood plain development.

Three locks and dams on the Green River provide 149 miles of slack water on that river. A fourth small lock and dam at mile 149 built in the 1830's that was breached in 1965 and another on Barren River extended the navigation 31 miles upstream to Bowling Green, Kentucky. After the uppermost Green River dam was breached in 1965; its lock as well as the Barren River lock were closed to navigation, and no freight has since moved on the 31 waterway miles above the breached dam. The two locks, however, have not been deactivated, and restoring navigation to Bowling Green is under study. The two lower Green River dams with 84 by 600 foot locks provide a nine foot depth channel for the lower 106 miles. Upstream from that point, the dimensions of locks and channel are inadequate to serve normal waterway carriers. Facilities in the existing system provide for a freight traffic capability of two billion ton-miles annually.

Several communities in the subbasin are served entirely by wells or springs; however, flowing streams have been tapped as the principal source of major municipal and industrial water supplies. Several small impoundments provide small public sources of supply. Rural and farm water supply needs are served primarily from ground water sources.

In 1963, steam plant capacity was 1,681 megawatts; however, there were no hydroelectric generating plants in the subbasin.

Recreation facilities at Federal and other reservoirs in 1960 provided 900,000 recreation days, 1.1 million angler days and 700,000 hunter days. Over 54,000 acres have been set aside for recreation pursuits within the Mammoth Cave National Park. One national historic site and five fish and wildlife areas formed the balance of recreation areas in the Green subbasin. The Barren, Nolin and Green Federal multiple-purpose reservoirs completed since 1960 add a total of about 24,000 acres of recreational water; this with the related lands increases the recreational opportunity.

b. Future Demand. Base year amounts and projected increase in demand for water and related functions and services which will intensify demand for further use, development and management of water and related land resources are shown in table GR-1.

Water withdrawal demands are projected to exceed 4.7 billion gallons per day by 2020, an increase of more than 3.5 billion gallons per day over withdrawals in 1960. Water withdrawals for cooling thermal electric generating plants constitutes nearly 97 percent of the total withdrawals projected for 2020.

Adequate streamflow to provide waste assimilation capacity, within acceptable standards of quality, will be required to absorb organic waste loads that are projected by 2020 to total five times those existent in 1960.

Residual average annual damages after completion of projects in the going program for flood control would be about 4.2 million dollars. By 2020, unless additional protection works are provided and management actions taken to prevent them, potential average annual damages are estimated to become 7.5 million dollars with projected conditions of flood plain development. The potential damages are about equally divided between the upstream and downstream areas of the subbasin.

Replacement of the obsolete navigation facilities in the upper waterway section and provision of a greater channel depth in the lower Green River will be required to accommodate the projected annual traffic of 4.1 billion freight ton-miles by 2020.

The amount of hydroelectric power that can be utilized specifically in the Green River subbasin has not been estimated; however, it is anticipated that all potential hydroelectric power development can be utilized in conjunction with the thermal generating plants, particularly for meeting the peak portion of power loads.

Land area requiring treatment and management for efficient use is projected to total over 3.6 million acres by 2020. Land areas in need of rehabilitation because of strip mining amount to 18,100 acres. Irrigated land area is relatively small, being 1,000 acres in 1960; the projected increase for 2020 is 7,800 acres. Land that may be drained economically is projected to increase an additional 140,000 acres by 2020 to more than double the 1960 acreage.

The demand for outdoor recreation is predicted to increase greatly, to about 27 million recreation days by 2020. This demand in conjunction with increased hunting and fishing demands will require full use of all resource potentials associated with water resource development.

3. Resource Availability. The potential for water resource developments in the tributary valley areas provide favorable opportunities to develop stream regulation reservoirs. One potential reservoir, Drakes Creek, has been investigated in some detail and is currently considered feasible. Total storage potentials identified, over and above that now developed, is over 1,110,000 acre-feet. Forty-five potential watershed projects have been investigated which cover 3,431 square miles.

Ground water in moderate supplies is available from limestone and sandstone aquifers in most of the subbasin. Supplies are also available in the alluvium deposits along Green River and other streams. In the

eastern limestone area yields are erratic, and it may be difficult to find sufficient supply for domestic use. Conservation of surface waters will be required for water supply in this area.

The hydroelectric power potential of the Green subbasin has not been fully investigated, thus the amount of feasible capacity is not known. Because of the entrenched streams, pumped storage power projects with high head utilizing the reservoirs as upper or lower pools can be developed. There are three locations inventoried where hydroelectric power plants with a potential of about 102,000 kilowatts that may be feasible.

The Green subbasin has an abundant supply of potential recreation resources. There are many scenic and wooded areas and the topography is generally favorable for the creation of attractive recreational areas. It is reasonable to assume that the Green subbasin could, in the future, help alleviate a portion of unsatisfied demands in nearby areas.

4. Assessment of Resource Development Requirements. Principal water supply, water quality and flood problem areas, together with reservoirs and upstream watershed projects in the going program of development and those identified as potential future projects, are shown the subbasin map, figure GR-1. Summary data for identified potential projects are given in Appendix K, table 24 through 28. The relationship of problem areas and projects in the going program is shown schematically in figure GR-2, and key data relating to problem areas are given in table GR-2. The schematic diagram was used for general orientation in analyzing problems and needs and establishing development requirements for streamflow control. An accounting of storage capacity for streamflow control is given in table GR-3. Results of the subbasin assessment to determine the magnitude and costs of resource development required to satisfy projected demands for water and related functions and services are summarized in table GR-4.

a. Requirements to be Furnished by Identified Resource Potential. Analysis of demands for water and related functions and services and of the means whereby these demands can be satisfied indicates that to solve water supply, water quality, and flood problems, development of additional storage capacity for streamflow control will be required; also, further local protection projects and channel improvements will be required in several locations, either singly or in combination with streamflow regulation and flood plain management to better cope with flood problems.

The total storage capacity in addition to the amount that will be made available upon completion of the going program is estimated to be 3.3 million acre-feet. About 2.9 million acre-feet will be required for flood control and about 425,000 acre-feet will be required to provide for low

flow requirements. Joint use of seasonal flood control storage could reduce the total required by about 100,000 acre-feet.

Twenty-two areas in need of additional water supply or water quality improvement by 2020 have been identified. Most of these needs can be met by existing reservoirs aided by new strategically located reservoirs. Storage capacity of 129,000 acre-feet, including 94,000 acre-feet of flood storage capacity that can be utilized on a seasonal joint use basis, is included in identified potential reservoirs.

The flood control plan for the Green subbasin consists of 45 watershed projects, including 192 upstream detention structures with 201,000 acre-feet of flood detention capacity and 296 miles of channel improvement, one reservoir, with 270,000 acre-feet of flood control capacity and two small local protection projects, in addition to the going program. An aggressive flood plain management program will assist in maintaining a high percentage of damage reductions that the proposed protection will afford. Additional potential storage for flood control on Ohio River below the Wabash River and assigned to that subbasin could be provided in the Green River subbasin as an alternative.

Traffic on the Green River has been growing steadily with the increasing demand for coal for electric power generation both in and outside the study area. Construction of a new multiple-purpose dam, with a lock, near Rochester, Kentucky, will replace the obsolete navigation system on the upper Green River from Dam No.3 to Brownsville and on the Barren River to Bowling Green. The 9-foot channel depth would accommodate the water transport demands of manufacturing, mining, and attendant activities in the area. The channel depth of the 109 miles of waterway below Rochester should be deepened and made compatible with the future deepening of the Ohio River waterway.

The availability of streams with improved water quality and additional reservoirs and upstream watershed developments would provide potential opportunities for 14 million outdoor recreation days annually if access and facilities are made available.

b. Remaining Requirements. The 296,000 acre-feet of added storage capacity to supplement streamflows during low flow periods is needed in the downstream portion of the subbasin. The potential locations of this storage development requirement has not been identified.

In addition to the 471,000 acre-feet of storage in identified sites, about 2.4 million acre-feet of storage would be required for subbasin flood control and also furnish a portion of the capacity required for flood stage reduction on the Ohio River.

The part of the demand for outdoor recreation, hunting, and fishing opportunity that can be satisfied beyond that provided by identified developments has not been assessed. A portion of the remaining recreation need can be met in conjunction with other needed water resource developments in the subbasin. The remainder may be provided by single-purpose recreation lakes, state and local parks and private developments.

Remaining land treatment and management requirements are associated with the general land base outside watershed projects, with the exception that lands to be irrigated or drained may be in or outside the watershed projects. By 2020 about 1.6 million acres of cropland, pasture and woodlands would be subject to management and treatment measures, such as contour farming, controlled grass land and improved forest harvesting. These lands are accounted for in the general inventory of requirements but are not identified by specific location.

TABLE GR-1

GREEN SUBBASIN
DEMAND FOR WATER AND RELATED FUNCTIONS AND SERVICES

	Unit	Base Year Amount	Projected Increase[1] 1980	2020
Water Withdrawal				
Municipal and Industrial[2]	Million Gallons Per Day	19.2	12.4	92.4
Electric Power Cooling	Million Gallons Per Day	1,170	880	3,430
Rural Communities	Million Gallons Per Day	12.5	10.9	25.0
Rural Domestic and Livestock	Million Gallons Per Day	9.19	0	3.13
Irrigation[3]	Million Gallons Per Day	0.6	0.5	3.6
Stream Assimilation of Organic Waste Effluent[4]	1,000 Population Equivalents	27.2	16.8	110.7
Flood Damage Prevention[5]	Million Dollars Annually	2.81	4.83	7.52
Waterway Freight Movement[6]	Million Ton-Miles Annually	2,000	0	2,100
Hydroelectric Power - Installed Capacity	Megawatts	0	(Assessed on a basin-wide basis)	
Outdoor Recreation	Million Recreation Days	0.9	9.2	25.7
Sport Fishing	Million Angler Days	1.10	0.44[7]	1.40[7]
Hunting	Million Hunter Days	0.70	0.12[7]	0.27[7]
Commercial Fishing			(Assessed on a basin-wide basis)	
Land Treatment and Management	1,000 Acres	828	960	2,821
Drainage	1,000 Acres	122	101	140
Irrigation (Land Area)	1,000 Acres	1.0	1.1	7.8

NOTES: (1) Base year amounts plus projected increase equals gross demands.

(2) Mining industry water requirements not included; assessed on a basin-wide basis.

(3) Withdrawal shown is for average year; drought year may be 45 percent higher.

(4) Residual biochemical oxygen demand after 85 percent waste removal by treatment.

(5) The dollar amounts (1980 and 2020) are indices to the magnitude of the problem and the protection measures required to reduce the potential damaging effects of floods.

(6) An index to the canalization and waterway facilities required to accommodate the transport of waterborne freight.

(7) Net requirements.

TABLE GR-2

GREEN SUBBASIN
PRINCIPAL CONSIDERATIONS IN DETERMINING STORAGE CAPACITY REQUIREMENTS
FOR CONTROL OF STREAMFLOW

A. SUPPLEMENTAL STREAMFLOW REQUIRED AT KEY LOCATIONS TO CONTROL WATER QUALITY (CFS).

Problem Area (1)	Stream	Required Flow (2) 1980	Required Flow (2) 2020	Flow Provided by Going Program	Supplemental Flow Required 1980	Supplemental Flow Required 2020
Liberty, Ky	Green River	4	9	0	4	9
Columbia, Ky	Russell Creek	7	17	0	7	17
Campbellsville, Ky	Pittman Creek	20	52	0	20	52
Hodgenville, Ky	Nolin River	5	9	0	5	9
Elizabethtown, Ky	Valley Creek	11	17	0	11	17
Tompkinsville, Ky	Mill Creek	5	11	0	5	11
Glasgow, Ky	Scraggs & Beaver Creeks	34	56	0	34	56
Scottsville, Ky	Barren River, Bays Fork	7	18	0	7	18
Franklin, Ky	Drakes Creek	10	25	0	10	25
Portland, Tenn	Drakes Creek	5	10	0	5	10
Bowling Green, Ky	Barren River	70	130	53	17	77
Russellville, Ky	Mud River, Town Branch	16	40	0	16	40
Central City, Ky	Cypress Creek	9	15	0	9	15
Lietchfield, Ky	Bear Creek	5	14	0	5	14
Hartford, Ky	Rough River	20	30	15	10	15
Beaver Dam, Ky	Muddy Creek	3	7	0	3	7
Greenville, Ky	Caney Creek	6	15	0	6	15
Madisonville, Ky	Flat Creek	24	56	0	24	56

B. WATER REQUIRED TO SATISFY DEMANDS FOR WITHDRAWAL AND USE (IN ADDITION TO THAT PROVIDED IN BASE YEAR) (MGD).

Item	1980	2020
1. Total withdrawal (3)	904	3,554
2. To be provided by groundwater	3	17
3. Total consumptive use	23	110

C. FLOOD DAMAGE AREAS.

Location	Residual Damages (4) (Millions Dollars)	
1. Upstream areas	2.18	
2. Major urban areas		
No major urban flood problem areas within the scope of this study.		
3. Other flood plain areas	2.03	
4. Total subbasin	4.21	Projected to 4.83 in 1980 and 7.52 in 2020.

NOTES: (1) See figure GR-1 for geographic location of principal problem areas and figure GR-2 for schematic relationship.

(2) Streamflow required to maintain a minimum of 4 parts per million of dissolved oxygen.

(3) Water required to satisfy municipal and industrial, electric power cooling, rural community, rural domestic and livestock, and irrigation demands.

(4) Estimated average annual damages with the 1965 flood control program completed (1965 constant dollars).

TABLE GR-3

GREEN SUBBASIN
ACCOUNTING OF STORAGE CAPACITY FOR STREAMFLOW CONTROL
(IN ADDITION TO THAT PROVIDED IN THE GOING PROGRAM)

	Time Period 1980	2020
	Storage (1,000 Ac Ft)	
A. WATER QUALITY CONTROL.		
1. Storage required(1)	173.4	358.4
2. Storage provided in identified potential sites	10.7	14.3
3. Additional storage required	162.7	344.1
B. WATER WITHDRAWALS.		
1. Storage required	14.4	67.0
C. FLOOD CONTROL.		
1. Subbasin and Ohio River control requirement	667.6	2,873.0
2. Storage provided in identified potential sites	67.1	471.0
a. for solving localized problems	(67.1)	(201.0)
b. effective in controlling both subbasin and Ohio River flows	(0)	(270.0)
3. *Additional storage required*(2)	600.5	2,402.0
D. TOTAL STORAGE REQUIREMENT.		
1. Water quality control, water withdrawals, and flood control	855.4	3,298.4
2. Available in identified potential sites(3)	88.3	505.9
3. Joint use storage	13.4	94.2
4. Additional storage required(4)	753.7	2,698.3

NOTES: (1) Storage capacity required to provide supplemental flows at key urban locations and rural communities in upstream watershed areas.

(2) Remaining Green subbasin share of storage required to reduce the Ohio River Basin Standard Project Flood to the maximum flood stage of record.

(3) See figure GR-1.

(4) Terrain indicates storage sites are potentially available.

TABLE GR-4

GREEN SUBBASIN
SUMMARY ASSESSMENT OF RESOURCE DEVELOPMENT REQUIREMENTS

Program Elements	Unit	Provided in Going Program	Additional Requirement (1)			
			1980		2020 (Accumulative)	
			Amount	Capital Cost ($1,000)	Amount	Capital Cost ($1,000)
PART 1. TO BE FURNISHED BY IDENTIFIED RESOURCE POTENTIAL WITHIN SUBBASIN.						
A. Streamflow Control and In-Stream Use						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	752.1	21.2	2,600	34.9	5,400
2. Control of Flood Flows						
a. reservoir and detention storage	1,000 Ac Ft	2,125.5	67.1	11,200	471.0	119,800
b. local protection projects	Miles	64.0	0	0	0	0
c. channel improvement	Miles	206	99	4,300	296	12,900
3. Navigable Waterway						
a. improvement to existing waterway	Miles of Channel	212	0	0	212	15,000
b. new waterway	Miles of Channel	-	-	-	-	-
c. channel deepening to 12 feet	Miles of Channel	-	0	0	109	2,000
4. Hydroelectric Power - Installed Capacity	Megawatts	0	102	11,500	(Assessed on a Basin-wide Basis)	
B. Related Programs						
1. Outdoor Recreation (2)(3)	Million Recreation Days	0.9	4.1	12,600	13.9	43,200
2. Watershed Project Land Treatment and Management (4)	1,000 Acres	828	416.1	10,400	1,245.7	31,100
	COSTS - PART 1			52,600		229,400
PART 2. REMAINING REQUIREMENTS.						
A. Streamflow Control and In-Stream Use (5)						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	-	153.2	39,100	296.3	75,600
2. Storage for Control of Flood Flows	1,000 Ac Ft	-	600.5	153,100	2,402.0	612,500
3. Hydroelectric Power				(Assessed on a Basin-wide Basis)		
B. Related Programs						
1. Outdoor Recreation (2)(6)	Million Recreation Days	-	5.1	16,800	11.8	38,800
2. Fish and Wildlife						
a. sport fishing (2)(6)	Million Angler Days	1.10	0.44	1,500	1.40	4,900
b. hunting (2)(6)	Million Hunter Days	0.70	0.12	400	0.27	900
c. commercial fishery				(Assessed on a Basin-wide Basis)		
C. Land Treatment and Management						
1. Lands Outside Watershed Projects	1,000 Acres	-	544.0	13,600	1,575.2	39,400
2. Irrigation (Acres to be Irrigated)	1,000 Acres	1.0	1.1	100	8.8	800
3. Drainage	1,000 Acres	122	125.1	16,900	171.7	23,200
	COSTS - PART 2			241,500		796,100
	TOTAL COSTS - (PARTS 1 AND 2)			294,100		1,025,500

NOTES:

(1) Requirement in addition to that provided by going development programs.

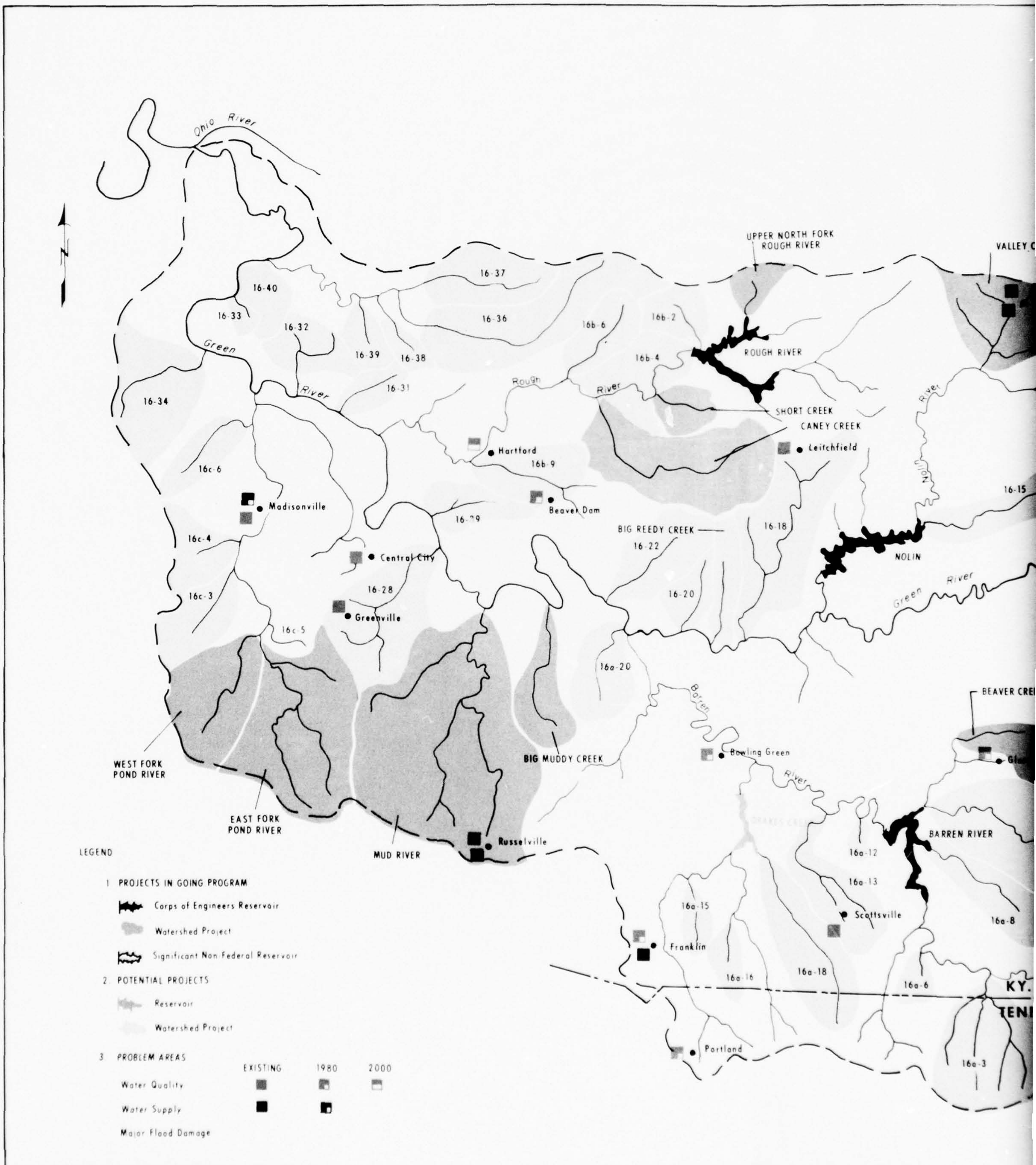
(2) Costs shown are for initial facilities and such measures as may be required to implement the program, and do not include water and related land cost. Base year 1960.

(3) The number of outdoor recreation days shown include some sport fishing and hunting which could not be separately accounted for in available data.

(4) Land area and costs shown are for total land treatment and management requirements in watershed projects and cover both water resource development related and other lands.

(5) Specific sites to provide storage capacity for streamflow control are not identified; however, favorable storage sites are potentially available.

(6) Because of population and resource distributions, remaining subbasin requirements for outdoor recreation, sport fishing and hunting not satisfied by water resource developments may require a trade off with adjacent subbasins or satisfied by other means.


Ohio River
Green River
Rough River
Nolin River
Green River
Barren River
UPPER NORTH FORK ROUGH RIVER
VALLEY C
16-37
16-40
16-33
16-36
16-32
16b-6
16b-2
16-39
16-38
16b-4
ROUGH RIVER
16-31
16-34
SHORT CREEK
CANEY CREEK
Hartford
16b-9
Leitchfield
16c-6
Madisonville
Beaver Dam
16-15
16-29
BIG REEDY CREEK
16-18
16c-4
16-22
Central City
NOLIN
16-28
16c-3
16-20
Greenville
16c-5
16a-20
BEAVER CRE
WEST FORK POND RIVER
BIG MUDDY CREEK
Bowling Green
EAST FORK POND RIVER
BARREN RIVER
Russelville
MUD RIVER
16a-12
16a-13
16a-15
Scottsville
16a-8
Franklin
16a-16
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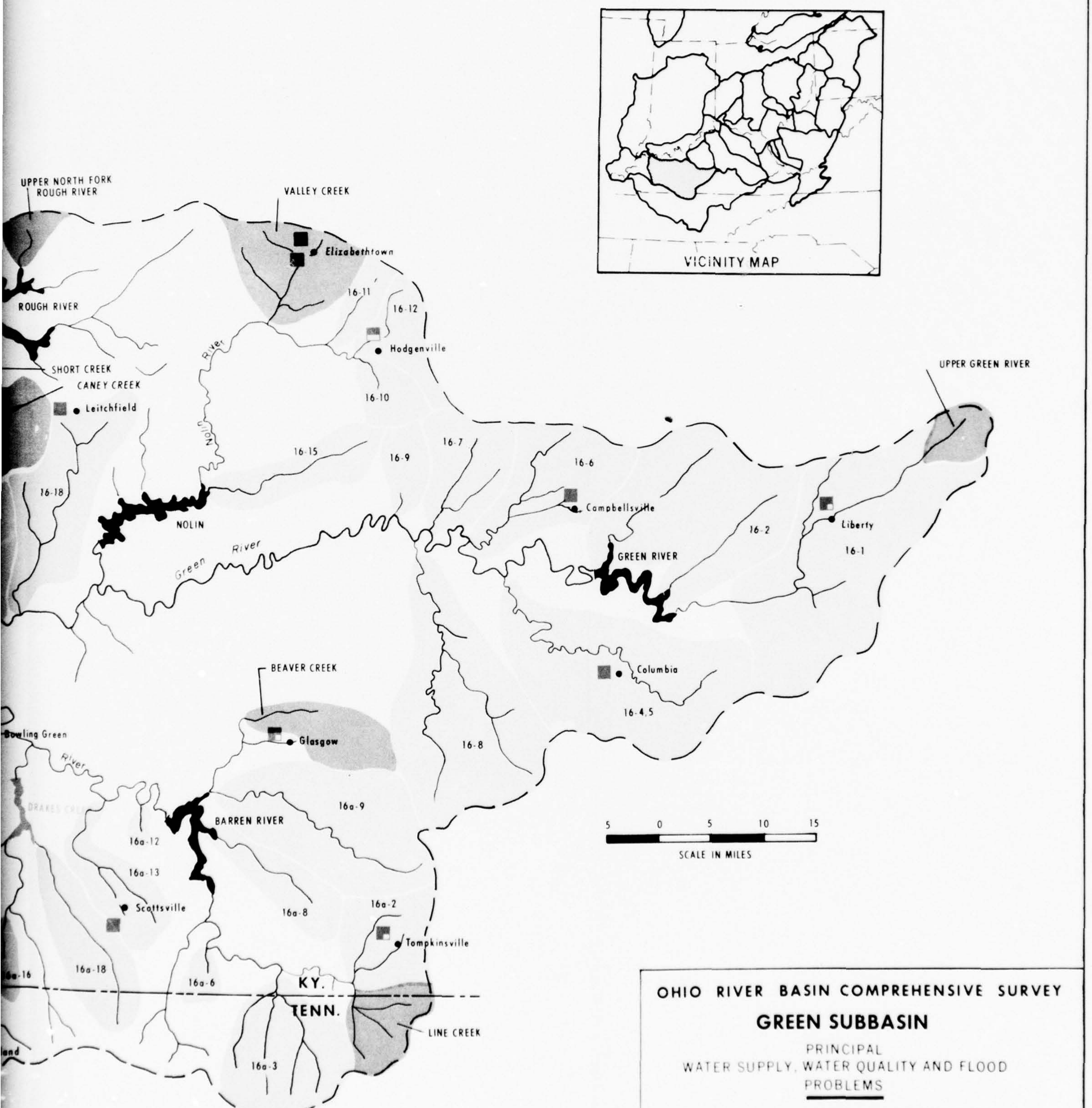

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IN GOING PROGRAM, AND POTENTIALS

CORPS OF ENGINEERS — U.S. ARMY OHIO RIVER DIVISION
APPENDIX K — FIGURE GR-1

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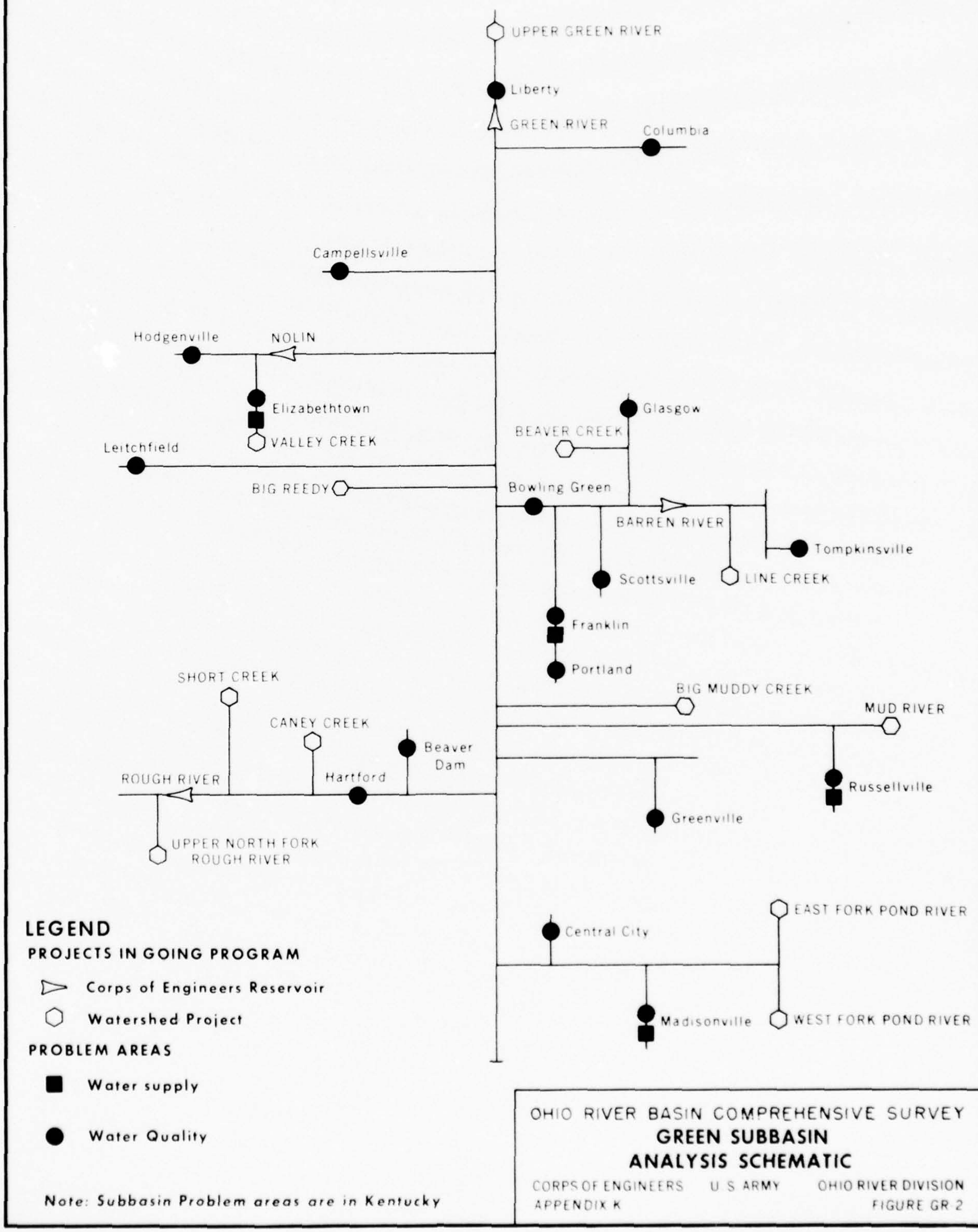


OHIO RIVER BASIN COMPREHENSIVE SURVEY
GREEN SUBBASIN ANALYSIS SCHEMATIC
CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION
APPENDIX K FIGURE GR 2

1. Planning Environment. The Wabash River subbasin, situated in the extreme northwest portion of the Ohio River Basin contains 33,100 square miles, or 20 percent of the Ohio Basin study area. It includes a small portion of western Ohio, most of Indiana and a considerable portion of southeastern Illinois. Exclusive of the southeastern portion, which is hilly and rolling, the drainage area in general is a glaciated region of moderate relief, wherein the streams have gentle slopes and broad flat valleys. Natural drainage in the northern part of the basin is very poor.

The pattern of sociological development of the Wabash subbasin has been typical of that section of the country known as the Middle West. In 1818 the Treaty of St. Marys opened the former Indian territory of the Wabash subbasin to settlement. The rich soils, wooded areas and wildlife made conditions ideal for a self-contained economy, and as a result many small urban centers and rural communities came into being.

The subbasin has a history of recurring heavy rains from widespread storms, summer thunderstorms with intense rainfall, and occasional tornadoes. Although storms are more frequent during the months of October to April, records show that they may occur at any time during the year. Average annual runoff per square mile is the lowest of any subbasin; nevertheless, flooding occurs frequently. The growing season is longer than the average for the Ohio Basin. Extended droughts, although infrequent, have caused acute water shortages and major crop losses.

The Wabash subbasin has about 19 percent of the population, 13 percent of the labor force and produces 17.5 percent of the Ohio Basin's industrial output. The western part of the subbasin contains large commercial coal deposits and mining output is increasing to keep pace with the growing needs of the electric power industry. Agriculture is also an important sector of the economy. Projective economic studies indicate that the general economy of the Wabash subbasin will continue to grow at a rate greater than the average for the overall Ohio Basin.

2. Demand for Water and Related Functions and Services. Greater use, additional development and increased efficiency in management of water and related land resources, along with diligent prosecution of other programs allied to water and land use will be required to keep abreast of the projected demands for water and related functions and services in the Wabash subbasin. The base year and projected increases that comprise gross demands for water and related functions and services are listed in table WA-1. Table WA-2 provides the principal considerations in determining storage capacity requirements for control of streamflow.

About one-third of all the average annual flood damages in the Ohio Basin occur in the Wabash subbasin. Agricultural damages are particularly high. There are three major urban centers in the subbasin with

flood problems. One of these, Indianapolis, Indiana, has the third highest residual annual damages of any city in the Ohio Basin.

In general, municipal and industrial water supplies are adequate in quantity. However, there are water supply problems in many rural areas. Population concentrations and economic activity in various parts of the subbasin has resulted in the aggravation of problems associated with municipal and industrial waste and other stream pollution. Acid drainage from active and abandoned mines has further degraded the streamflow in the Patoka River area of the subbasin. In addition, oil field brines are a problem in some streams.

The coal mining industry with large coal reserves in the central part of the subbasin, together with the energy producing and other industries, depend on the availability of low-cost transportation for the movement of bulk commodities. Therefore, it is expected that with this growing demand for a low-cost means for the transport of coal, petroleum, fertilizers and other bulk commodities, canalization of the lower Wabash will become economically feasible sometime after 1980.

Demand for water oriented outdoor recreation in the Wabash subbasin exceeds all other subbasins in the Ohio River Basin. This unusually high demand is directly related to the large population situated within the zone of this subbasin's recreational influence Primary population centers which circumscribe the area are St. Louis, Missouri; Springfield, Decatur, Peoria and Chicago, Illinois; Toledo, Dayton, and Cincinnati, Ohio; and Louisville, Kentucky; and Gary, Hammond, East chicago, South Bend, and Fort Wayne, Indiana. Champaign-Urbana, Illinois, and Muncie, Terre Haute and Indianapolis, Indiana, are major population centers within the subbasin. If predicted future recreational desires are to be satisfied, further sources of opportunity will be required.

a. <u>Going Program Accomplishments</u>. Resource development and management programs by Federal, state and local interests have been effective in controlling flooding, improving water quality, providing for outdoor recreation, sport fishing, hunting and other demands and implementing land treatment and management practices. The latter not only increases land productivity, but improves conditions for retention of runoff and control of erosion.

Streams within the subbasin have been tapped as the principal source for major municipal and industrial water withdrawals; about 64 percent is taken from surface water sources. Water supply impoundments, in most cases, serve as small public sources of supply. Rural and farm water supply needs are served primarily from ground water sources.

The going program of development included many Federal and non-Federal projects, of which a brief description follows. In July 1965, there were two existing Federal multiple-purpose reservoirs in the subbasin and four

under construction which provide a total of 1,320,000 acre-feet of storage for control of floods, 160,000 acre-feet of storage for low flow supplementation and 141,000 acre-feet of storage in joint use for both purposes. These six reservoirs will control runoff from 3,016 square miles or about nine percent of the total subbasin area. Also included in the going program are seventeen major Federal local protection projects, consisting of floodwalls, levees and channel improvements. The foregoing projects, when all are complete, would prevent about 48 percent of the average annual damages that would occur in downstream areas under 1965 level of flood plain development without the projects. In addition there were 16 upstream watershed projects authorized as of July 1965, which will control about 350 square miles of drainage area. These projects have 78 sites with a total capacity of 82,271 acre-feet for floodwater storage, sediment control and other uses and include 306 miles of channel improvements for rural flood protection and would prevent about two percent of the potential average annual damages in upstream areas. Two major, local protection projects at Indianapolis, Indiana, and numerous agricultural levees were completed by local interests and provide various degrees of protection.

There are a number of thermal electric generating stations in the subbasin, but there are only two hydroelectric plants with a total capacity of 17.7 MW.

Recreation facilities have been provided at reservoirs, impoundments, and along the many natural streams in addition to the numerous state parks, forests and recreation areas in the subbasin. Development and management programs have been put into effect to improve land cover and provide facilities for recreation, hunting and fishing throughout the subbasin. Stream pollution clean-up efforts have enhanced these programs. Even so, provisions for outdoor recreation have not kept pace with demand.

Much progress has been made in land treatment and management in this subbasin. Much of the land laid bare by strip mining has been reclaimed and rehabilitated. Over six million acres of land have been drained, and supplementary irrigation is practiced on over 17,000 acres.

A detailed comprehensive study of the water and related land resources of the Wabash subbasin is underway with completion scheduled for 1969.

b. Future Demand. Water withdrawals in the Wabash subbasin in 1960 were about nine percent of the total for the Ohio Basin study area. By 2020, the relative percentage will increase to 20 percent. Water withdrawals for all purposes in the Wabash subbasin will exceed 19 billion gallons per day by 2020, a seven-fold increase over the amount withdrawn in 1960. Water demand for electric power cooling purposes by 2020 will account for approximately 85 percent of withdrawals and municipal and industrial demand about 11 percent. Demand for supplemental irrigation

water is projected to increase to 380 million gallons per day, over 40 times 1960 use. In terms of total withdrawal demand, this irrigation water demand is a small amount; however, since practically none of the water is returned to streams for further use, the losses incurred are quite significant.

The total organic waste load in the Wabash subbasin is surpassed only by that in the Kanawha subbasin. Sufficient streamflow to provide waste assimilation capacity within acceptable standards of quality will be required to absorb organic waste loads that are projected to be, by 2020, four times those existent in 1960. These waste loads are the residuals after removal of 85 percent of the BOD by treatment plants before discharge of sewage effluent. The problem areas are many and widely distributed, but the concentration of wastes in the White River below Indianapolis, Indiana, create, by far, the most serious problem.

Because of the wide flood plains and low stream gradients, large land areas are inundated during floods. Many stream channels have very limited capacities and overbank flow is very frequent. Projects previously mentioned in the going program for flood control will prevent 18.7 million dollars in average annual flood damages under 1965 level of flood plain development. However, remaining damages amount to over 36 million dollars and with flood plain development projected for 2020, additional protective works and management programs will be needed to prevent potential flood damages which may be twice this annual amount.

Development of a modern waterway for freight transport on the Wabash River would substantially meet the demand for waterborne commerce in the area. It is estimated that traffic would average 1.9 billion ton-miles annually by 2020.

Additional electric power generation will be required to support industrial expansion and the general growth of the economy. By 1980, it is estimated that approximately eight million kilowatts will be installed in the Wabash subbasin, with about 40 percent of this in the tributary White River subbasin. With the exception of the two small existing and three identified potential hydroelectric plants, it is expected that all of the capacity will be in thermal or nuclear-fired generating stations.

By 2020, land area requiring treatment and proper management for efficient use is projected to increase 11.3 million acres in addition to land accounted for in authorized upstream watershed projects. Irrigated land area is projected to increase an additional 774,000 acres, whereas land that may be economically drained will increase an additional 2.8 million acres.

The demand for outdoor recreational opportunities is predicted to increase tremendously, reaching nearly 200 million recreation days by

2020. This demand, in conjunction with increased hunting and fishing pressure, will require full utilization of all potentials affiliated with water resource development.

3. Resource Availability. Excellent ground water sources are available in most parts of the Wabash subbasin, for about 13,000 square miles in the southern and southwestern parts outside the major stream valleys. Ground water in large supplies is available from limestone and dolomite aquifers in the northeastern part of the basin. Nearly all of the stream valleys contain thick deposits of sand and gravel, which are good sources of well water. Water from both the unconsolidated glacial deposits and from bedrock formations is very hard. Yields can generally be expected to be in excess of 100 gallons per minute and in a few areas as much as 1,500 gallons per minute.

Twenty-nine potential reservoirs have been investigated in some detail and are considered feasible. The reservoirs would provide nearly 7 million acre feet of total storage capacity for control of runoff from more than 16,700 square miles of drainage. There are 198 potential upstream watershed projects containing sites for 591 water detention structures which would provide control of runoff from 4,463 square miles of upstream watershed area. The total potential storage capacity within the watershed projects is about 3.7 million acre-feet of which only 1.3 million acre-feet of active storage is in the streamflow control program. Potential reservoirs and watershed projects effective and utilized along with those in the going program are shown on the subbasin map, figure WA-1.

The availability of storage sites in the Wabash subbasin makes it a key area for Ohio River control in the reach below the mouth of the Wabash River. Also, development of the storage potential will provide opportunities for the satisfaction of demands for outdoor recreation, sport fishing and hunting. Realization of the substantial potential for recreation development within the subbasin will require the provision of ready access to the resource areas and the construction of adequate facilities. Because of the proximity of the potential storage areas to large metropolitan centers tourist recreation activity would increase in importance with the provision of suitable access and facilities.

Due to the relatively flat terrain which is typical of most of the subbasin, the hydroelectric power potential is limited. Seven undeveloped sites with a total potential installed capacity of 245 megawatts have been identified. Four are on the White River and two on the Wabash River in Indiana, and one on the Vermilion River in Illinois. Future investigations may determine additional sites feasible of development.

4. Assessment of Resource Development Requirements. The principal water quality, water supply and flood problem areas, together with reservoirs and upstream watershed projects in the going program of development, and identified potential future projects, are shown on the subbasin map, figure WA-1. Summary data for projects in the going program are given in Appendix K, tables 15 through 21, and for identified potential projects in tables 24 through 28. The relationship of problem areas and projects in the going program is shown schematically in figure WA-2 and key data relating to problem areas are given in table WA-2. The schematic diagram provides orientation in analyzing problems and needs and establishing development requirements for streamflow control. An accounting of storage capacity for streamflow control is given in table WA-3. Results of the subbasin assessment to determine the magnitude and costs of resource development required to satisfy projected demands for water and related functions and services are summarized in table WA-4.

a. Requirements to be Furnished by Identified Resource Potential. Analysis of demands for water and related functions and services and of the manner by which these demands can be met indicates that the solution of water supply, water quality and flood problems will require additional storage capacity for streamflow control as well as flood plain management added local protection projects and rural channel improvements at selected locations. The local protection projects would serve alone or in combination with streamflow regulation in providing the best solution to the flood problems.

The aggregate amount of storage capacity required by 2020 in addition to the amount that will be available upon completion of the going program to provide streamflow control is estimated at 18.4 million acre-feet. About 14,650,000 acre-feet of reservoir capacity will be required for control of flood flows and 3,752,000 acre-feet to provide for low flow requirements. The combined requirement can be met with 17.1 million acre-feet of reservoir space, of which 1,277,000 acre-feet in identified projects would be utilized on a joint use basis.

Of this amount, 5,438,000 acre-feet would be provided in the 29 identified potential reservoirs. About 946,000 acre-feet or 25 percent of the total potential storage distributed in the 198 potential upstream watershed projects would be utilized for flood control. In addition to control by storage, major local protection works including 325 miles of levees and 32 miles of channel improvements have been identified to provide flood protection at 36 locations, and 1,701 miles of channel improvements are included in the potential upstream watershed projects. An aggressive flood plain management program will assist in maintaining the high percentage of damage reduction that will be afforded by proposed protection and control unwise use of flood plain lands.

WABASH

Storage capacity provided by projects in the going program will supply supplemental flows to assist in the control of water quality at 20 of 53 identified locations of need. However, flows to satisfy water quality requirements will be sufficient at only two locations, and by 2020 additional flows will be required at all 53 locations. Many of these locations also have water supply problems. By 2020, it is estimated that additional sources of water supply will be required at 37 locations.

About 2,568,000 acre-feet of the storage capacity required by 2020 to supplement streamflows during low flow periods for quality control and to provide for water withdrawals can be provided in identified potential reservoirs and upstream watershed projects, including the joint use of 1,277,000 acre-feet of flood control space. Advanced waste treatment in addition to flow supplementation will likely be needed to handle the heavy load of organic waste effluent discharged to the White River in the Indianapolis area. Storage capacity provisions for supplementing streamflows are limited to amounts which are beyond the capability of available surface and ground water sources to satisfy demands for water withdrawals and for increasing flows during low flow periods in the interest of water quality. The ground water potential is considered adequate to provide almost 570 million gallons per day toward meeting 2020 water requirements.

The navigation project contemplated for the Wabash subbasin would add 135 miles of canalized waterway to the Ohio River Basin navigation system. The waterway with 12-feet minimum depth and 200 feet minimum width would extend from the Ohio River via the Wabash River to Terre Haute, Indiana.

The identified hydroelectric power potential of 245 megawatts installed capacity should be useable before 1980 to meet a portion of the growing Ohio Basin power requirements; inclusion of the power potential as an element of water resource development is based on judgment that the installation will prove to be desirable and economically feasible in comparison to alternative sources of power supply.

Total area in potentially feasible upstream watershed projects is over 10.6 million acres. Of this amount, it is estimated that approximately 5.9 million acres of cropland, pasture, and woodland of which 80 percent is cropland and pastureland will require treatment and management to enhance land productivity and serve other beneficial purposes. Retardation of runoff, control of erosion, and thereby reducing sediment transport to streams are important.

The availability of clean streams, reservoirs, impoundments, and other developments would provide potential opportunities for over 79 million outdoor recreation-days annually if access and facilities are

made available. Of this amount, opportunity for 27.7 million annual recreation-days would be made available in potential upstream watershed projects.

b. Remaining Requirements. Storage capacity that can be made available in identified potential projects is sufficient to provide for subbasin flood control requirements and would also furnish a portion of the capacity required for flood stage reduction on the Ohio River. The 8.3 million acre-feet for which additional development will be required is the remaining amount needed in the Wabash subbasin to assist in regulating the Ohio River Standard Project Flood.

Storage capacity of 1.2 million acre-feet at unidentified sites is required to supplement streamflows during low flow periods. It includes an amount for water required in areas not identified by specific location of need and an amount required to provide stream regulation in several identified areas of need, but for which storage developments are not identified.

The extent to which the remaining 117 million recreation days, 2.2 million angler days and 1.4 million hunter days of recreation, sport fishing and hunting demand can be satisfied has not been defined. A portion of the remaining requirement can be met in conjunction with other needed water resource developments in the subbasin. However, further detailed study will be necessary to determine a plan that will best satisfy the recreational needs within the subbasin.

Remaining land treatment and management requirements are associated with the general land base outside potential watershed projects, with exception that lands to be irrigated or drained may be located in or outside watershed projects. By the year 2020, approximately 5.4 million acres of cropland, pasture, and woodland would be subject to treatment and management measures, some of the more common being contour farming of all types, controlled grassland farming, and improved forest management and utilization. It is expected that irrigated land will be expanded by 744,000 acres and 2.5 million acres of the 2.8 million acres showing economic potential will be drained by 2020. These lands are accounted for in the general inventory of requirements but are not identified by specific location.

TABLE WA-1

WABASH SUBBASIN
DEMAND FOR WATER AND RELATED FUNCTIONS AND SERVICES

	Unit	Base Year Amount	Projected Increase[1] 1980	2020
Water Withdrawal				
Municipal and Industrial[2]	Million Gallons Per Day	457.6	338.4	1,672.4
Electric Power Cooling	Million Gallons Per Day	2,188	2,067	14,302
Rural Communities	Million Gallons Per Day	91.2	6.8	57.5
Rural Domestic and Livestock	Million Gallons Per Day	37.54	20.03	69.69
Irrigation[3]	Million Gallons Per Day	9.0	34.9	371.3
Stream Assimilation of Organic Waste Effluent[4]	1,000 Population Equivalents	570.7	371.2	1,835.9
Flood Damage Prevention[5]	Million Dollars Annually	18.70	44.97	71.99
Waterway Freight Movement[6]	Million Ton-Miles Annually	0	320	1,900
Hydroelectric Power - Installed Capacity	Megawatts	17.7	(Assessed on a basin-wide basis)	
Outdoor Recreation	Million Recreation Days	1.9	73.2	196.1
Sport Fishing	Million Angler Days	3.60	0.03[7]	2.20[7]
Hunting	Million Hunter Days	3.81	0.60[7]	1.40[7]
Commercial Fishing			(Assessed on a basin-wide basis)	
Land Treatment and Management	1,000 Acres	802	4,013	11,291
Drainage	1,000 Acres	6,318	2,184	2,819
Irrigation (Land Area)	1,000 Acres	17.4	75.4	472.8

NOTES:
(1) Base year amounts plus projected increase equals gross demands.

(2) Mining industry water requirements not included; assessed on a basin-wide basis.

(3) Withdrawal shown is for average year; drought year may be 45 percent higher.

(4) Residual biochemical oxygen demand after 85 percent waste removal by treatment.

(5) The dollar amounts (1980 and 2020) are indices to the magnitude of the problem and the protection measures required to reduce the potential damaging effects of floods.

(6) An index to the canalization and waterway facilities required to accommodate the transport of waterborne freight.

(7) Net requirements.

TABLE WA-2

WABASH SUBBASIN
PRINCIPAL CONSIDERATIONS IN DETERMINING STORAGE CAPACITY REQUIREMENTS
FOR CONTROL OF STREAMFLOW

A. SUPPLEMENTAL STREAMFLOW REQUIRED AT KEY LOCATIONS TO CONTROL WATER QUALITY (CFS).

Problem Area[1]	Stream	Required Flow[2] 1980	Required Flow[2] 2020	Flow Provided by Going Program	Supplemental Flow Required 1980	Supplemental Flow Required 2020
Bluffton, Ind	Wabash River	20	35	5	15	30
Huntington, Ind	Wabash River	35	70	9	26	61
Wabash, Ind	Wabash River	36	70	26	10	44
Peru, Ind	Wabash River	26	125	87	0	38
Portland, Ind	Salamonie River	15	25	5	10	20
Union City, Ind	Little Mississinewa River	13	25	0	13	25
Hartford City, Ind	Lick Creek	13	25	0	13	25
Marion, Ind	Mississinewa River	65	110	16	49	94
Warsaw, Ind	Tippecanoe River	15	25	3	12	22
Frankfort, Ind	Prairie Creek	28	50	0	28	50
Kokomo, Ind	Wildcat Creek	60	100	4	56	96
Lebanon, Ind	Prairie Creek	30	60	0	30	60
Champaign-Urbana, Ill	West Branch Vermilion River	75	125	5	70	120
Rantoul, Ill	Salt Fork Vermilion River	25	45	5	20	40
Danville, Ill	Vermilion River	115	210	14	101	196
Crawfordsville, Ind	Sugar Creek	30	60	5	25	55
Paris, Ill	Sugar Creek	15	30	0	15	30
Robinson, Ill	Lamotte Creek	18	30	0	18	30
Mattoon, Ill	Kickapoo Creek	35	55	0	35	55
Charleston, Ill	Kickapoo Creek	20	30	0	20	30
Franklin, Ind	Youngs Creek	20	40	0	20	40
Greenfield, Ind	Brandywine Creek	20	40	0	20	40
New Castle, Ind	Blue River	35	65	15	20	50
Shelbyville, Ind	Blue River	50	30	37	13	263
Rushville, Ind	Flatrock Creek	20	40	0	20	40
Columbus, Ind	East Fork White River	76	170	76	0	94
Greensburg, Ind	Sand Creek	20	40	0	20	40
North Vernon, Ind	Vernon Fork	12	25	0	12	25
Scottsburg, Ind	Stuckers Fork	12	25	0	12	25
Austin, Ind	Muscatatuck River	12	25	0	12	25
Bloomington, Ind	Clear Creek	45	80	0	45	80
Oolitic, Ind	Salt Creek	20	40	0	20	40
Winchester, Ind	West Fork White River	10	20	0	10	20
Muncie, Ind	West Fork White River	75	125	2	73	123
Anderson, Ind	West Fork White River	85	300	36	49	264
Elwood, Ind	Duck Creek	20	30	0	20	30
Tipton, Ind	Cicero Creek	15	22	0	15	22
Indianapolis, Ind	West Fork White River	1,100	2,000	105	995	1,895
Greenwood, Ind	Pleasant Run	20	40	0	20	40
Greencastle, Ind	Big Walnut Fork	20	40	4	16	36
Brazil, Ind	Birch Creek	22	45	0	22	45
Washington, Ind	Hawkins Creek	22	45	0	22	45
Jasper, Ind	Patoka River	32	66	0	32	66
Huntingtonburg, Ind	Patoka River	32	66	0	32	66
Princeton, Ind	McCarty Ditch	15	30	0	15	30
Effingham, Ill	Little Wabash River	17	35	0	17	35
Lawrence, Ind	Fall Creek	10	20	0	10	20
Fort Benjamin Harrison, Ind	Fall Creek	15	25	5	10	20
Beech Grove, Ind	Lick Creek	10	20	0	10	20
Flora, Ill	Seminary Creek	10	20	0	10	20
Olney, Ill	Fox River	10	20	0	10	20
Fairfield, Ill	Johnson Creek	10	20	0	10	20
Speedway, Ind	Eagle Creek	10	20	0	10	20

B. WATER REQUIRED TO SATISFY DEMANDS FOR WITHDRAWAL AND USE (IN ADDITION TO THAT PROVIDED IN BASE YEAR) (MGD).

Item	1980	2020
1. Total withdrawal[3]	2,467	16,473
2. To be provided by groundwater	107	569
3. Total consumptive use	90	728

C. FLOOD DAMAGE AREAS.

Location	Residual Damages[4] (Millions Dollars)	
1. Upstream areas	16.08	
2. Major urban areas[1]	0.84	
Indianapolis, Ind, West Fork White River Columbus, Ind, Flatrock & Driftwood Rivers Marion, Ind, Mississinewa River		
3. Other flood plain areas	19.47	
4. Total subbasin	36.39	Projected to 44.97 in 1980 and 71.99 in 2020.

NOTES: (1) See figure WA-1 for geographic location of principal problem areas and figure WA-2 for schematic relationship.

(2) Streamflow required to maintain a minimum of 4 parts per million of dissolved oxygen.

(3) Water required to satisfy municipal and industrial, electric power cooling, rural community, rural domestic and livestock, and irrigation demands.

(4) Estimated average annual damages with the 1965 flood control program completed (1965 constant dollars).

TABLE WA-3

WABASH SUBBASIN
ACCOUNTING OF STORAGE CAPACITY FOR STREAMFLOW CONTROL
(IN ADDITION TO THAT PROVIDED IN THE GOING PROGRAM)

	Time Period 1980	2020
	Storage (1,000 Ac Ft)	
A. WATER QUALITY CONTROL.		
1. Storage required (1)	1,388.7	2,622.4
2. Storage provided in identified potential sites	90.9	280.5
3. Additional storage required	1,297.8	2,341.9
B. WATER WITHDRAWALS.		
1. Storage required	441.0	1,123.5
C. FLOOD CONTROL.		
1. Subbasin and Ohio River control requirement	4,000.1	14,656.1
2. Storage provided in identified potential sites	1,932.1	6,384.1
a. for solving localized problems	(323.7)	(946.4)
b. effective in controlling both subbasin and Ohio River flows	(1,608.4)	(5,437.7)
3. Additional storage required (2)	2,068.0	8,272.0
D. TOTAL STORAGE REQUIREMENT.		
1. Water quality control, water withdrawals, and flood control	5,829.8	18,408.0
2. Available in identified potential sites (3)	2,464.0	7,675.1
3. Joint use storage	386.4	1,276.8
4. Additional storage required (4)	2,979.4	9,456.1

NOTES: (1) Storage capacity required to provide supplemental flows at key urban locations and rural communities in upstream watershed areas.

(2) Remaining Wabash subbasin share of storage required to reduce the Ohio River Basin Standard Project Flood to the maximum flood stage of record.

(3) See figure WA-1.

(4) Terrain indicates storage sites are potentially available.

TABLE WA-4

WABASH SUBBASIN
SUMMARY ASSESSMENT OF RESOURCE DEVELOPMENT REQUIREMENTS

Program Elements	Unit	Provided in Going Program	Additional Requirements (1) 1980 Amount	1980 Capital Cost ($1,000)	2020 (Accumulative) Amount	2020 (Accumulative) Capital Cost ($1,000)
PART 1. TO BE FURNISHED BY IDENTIFIED RESOURCE POTENTIAL WITHIN SUBBASIN.						
A. Streamflow Control and In-Stream Use						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	304.6	531.9	113,100	1,291.0	259,800
2. Control of Flood Flows						
a. reservoir and detention storage	1,000 Ac Ft	1,376.1	1,932.1	469,800	6,384.1	1,627,600
b. local protection projects	Miles	189.6	85.0	34,300	356.9	77,700
c. channel improvement	Miles	306	568	18,300	1,701	53,800
3. *Navigable Waterway*						
a. improvement to existing waterway	Miles of Channel	0	-	-	-	-
b. new waterway	Miles of Channel	-	0	0	135	240,000
c. channel deepening to 12 feet	Miles of Channel	-	-	-	-	-
4. Hydroelectric Power - Installed Capacity	Megawatts	17.7	245	27,600	(Assessed on a Basin-wide Basis)	
B. Related Programs						
1. Outdoor Recreation (2)(3)	Million Recreation Days	1.9	24.8	86,500	79.0	275,300
2. Watershed Project Land Treatment and Management (4)	1,000 Acres	802	2,022.8	50,600	5,914.5	147,900
	COSTS - PART 1			800,200		2,682,100
PART 2. REMAINING REQUIREMENTS.						
A. Streamflow Control and In-Stream Use (5)						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	-	911.4	232,400	1,184.1	301,900
2. Storage for Control of Flood Flows	1,000 Ac Ft	-	2,068.0	527,300	8,272.0	2,109,400
3. Hydroelectric Power				(Assessed on a Basin-wide Basis)		
B. Related Programs						
1. Outdoor Recreation (2)(6)	Million Recreation Days	-	48.4	168,400	117.1	407,500
2. Fish and Wildlife						
a. sport fishing (2)(6)	Million Angler Days	3.60	0.03	100	2.20	7,700
b. hunting (2)(6)	Million Hunter Days	3.81	0.60	2,100	1.40	4,900
c. commercial fishery				(Assessed on a Basin-wide Basis)		
C. Land Treatment and Management						
1. Lands Outside Watershed Projects	1,000 Acres	-	1,989.9	49,700	5,376.1	134,400
2. Irrigation (Acres to be Irrigated)	1,000 Acres	17.4	75.4	7,000	774.4	71,300
3. Drainage	1,000 Acres	6,318	2,190.0	280,300	2,525.8	323,700
	COSTS - PART 2			1,267,300		3,360,800
	TOTAL COSTS - (PARTS 1 AND 2)			2,067,500		6,042,900

NOTES: (1) Requirement in addition to that provided by going development programs.

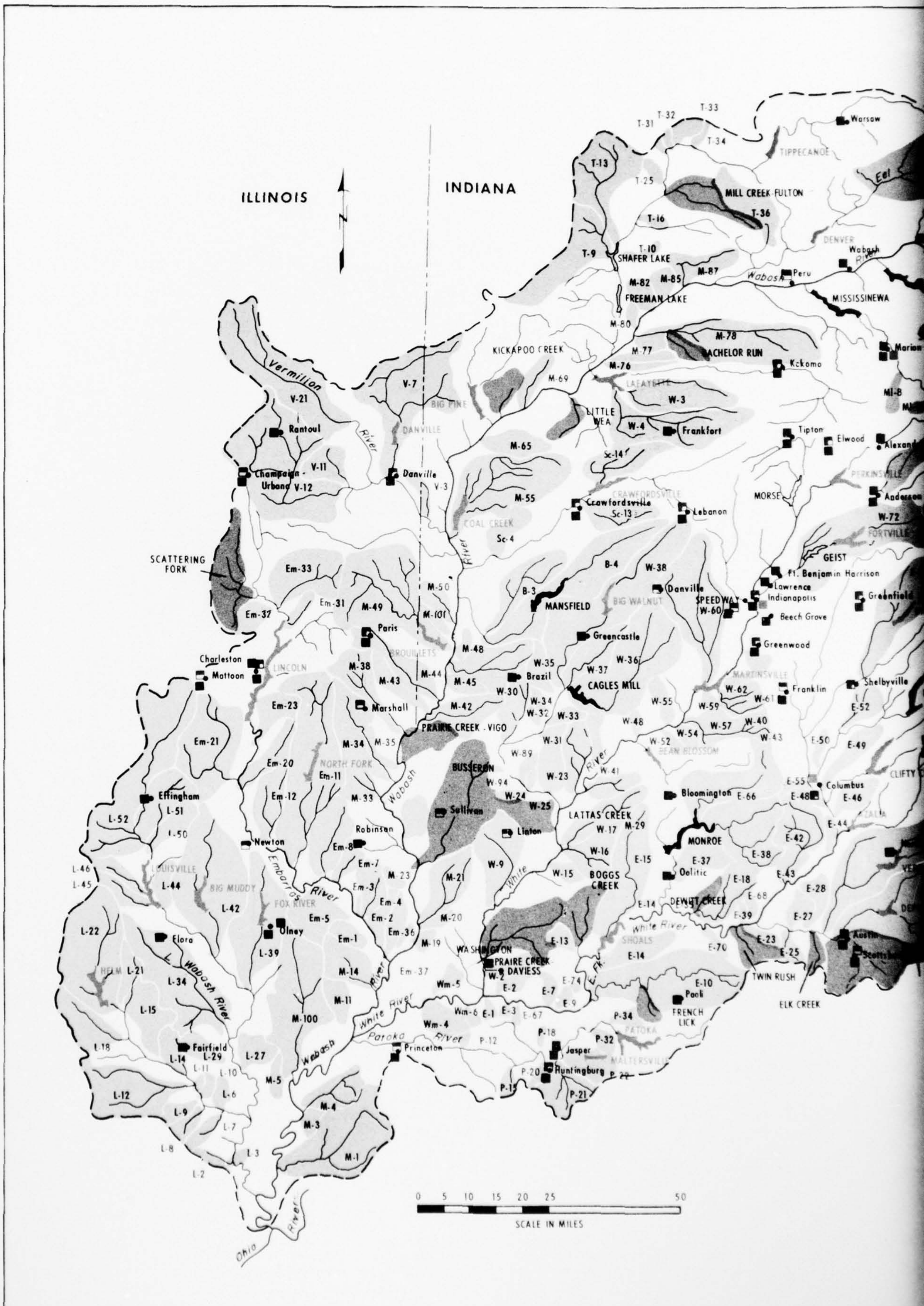
(2) Costs shown are for initial facilities and such measures as may be required to implement the program, and do not include water and related land cost. Base year 1960.

(3) The number of outdoor recreation days shown include some sport fishing and hunting which could not be separately accounted for in available data.

(4) Land area and costs shown are for total land treatment and management requirements in watershed projects and cover both water resource development related and other lands.

(5) Specific sites to provide storage capacity for streamflow control are not identified; however, favorable storage sites are potentially available.

(6) Because of population and resource distributions, remaining subbasin requirements for outdoor recreation, sport fishing and hunting not satisfied by water resource developments may require a trade off with adjacent subbasins or satisfied by other means.


ILLINOIS
INDIANA
N
Vermilion
River
Wabash River
White River
Patoka River
Embarras River
Ohio River
Eel
Rantoul
Champaign - Urbana
Danville
Charleston
Mattoon
Paris
Marshall
Effingham
Newton
Robinson
Olney
Flora
Fairfield
Princeton
Washington
Jasper
Huntingburg
Paoli
French Lick
Bloomington
Oolitic
Linton
Sullivan
Brazil
Greencastle
Crawfordsville
Lebanon
Frankfort
Kokomo
Tipton
Elwood
Anderson
Indianapolis
Lawrence
Beech Grove
Greenwood
Franklin
Shelbyville
Columbus
Greenfield
Speedway
Ft. Benjamin Harrison
Peru
Wabash
Warsaw
Marion
SCATTERING FORK
MANSFIELD
CAGLES MILL
PRAIRIE CREEK - VIGO
BUSSERON
MONROE
BOGGS CREEK
DEWITT CREEK
LATTAS CREEK
PRAIRE CREEK - DAVIESS
MILL CREEK-FULTON
SHAFER LAKE
FREEMAN LAKE
MISSISSINEWA
KICKAPOO CREEK
LITTLE WEA
TWIN RUSH
ELK CREEK
GEIST
MORSE
CLIFTY CREEK
0 5 10 15 20 25 50
SCALE IN MILES

OHIO RIVER BASIN COMPREHENSIVE SURVEY

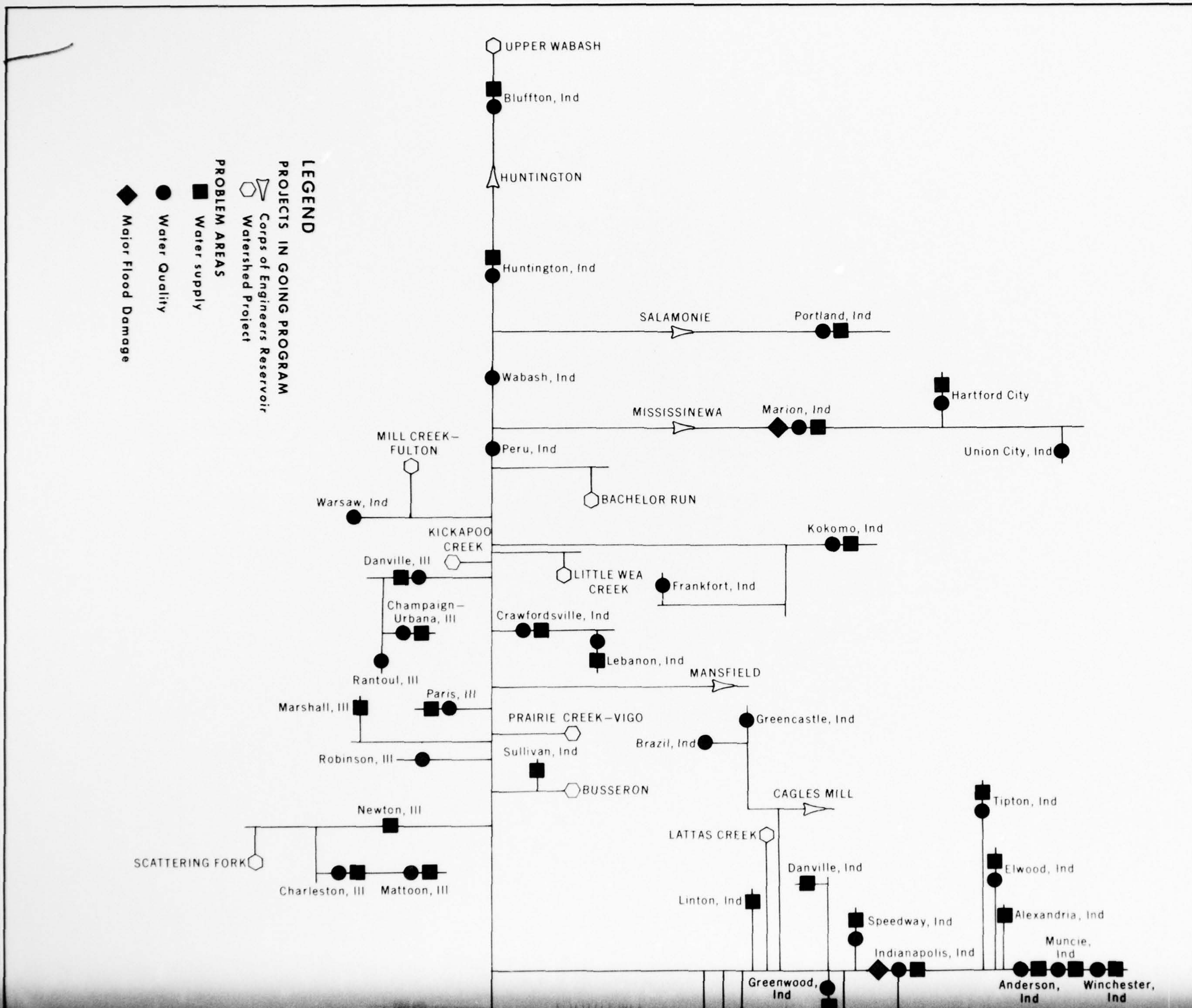
WABASH SUBBASIN

PRINCIPAL
WATER SUPPLY, WATER QUALITY AND FLOOD
PROBLEMS

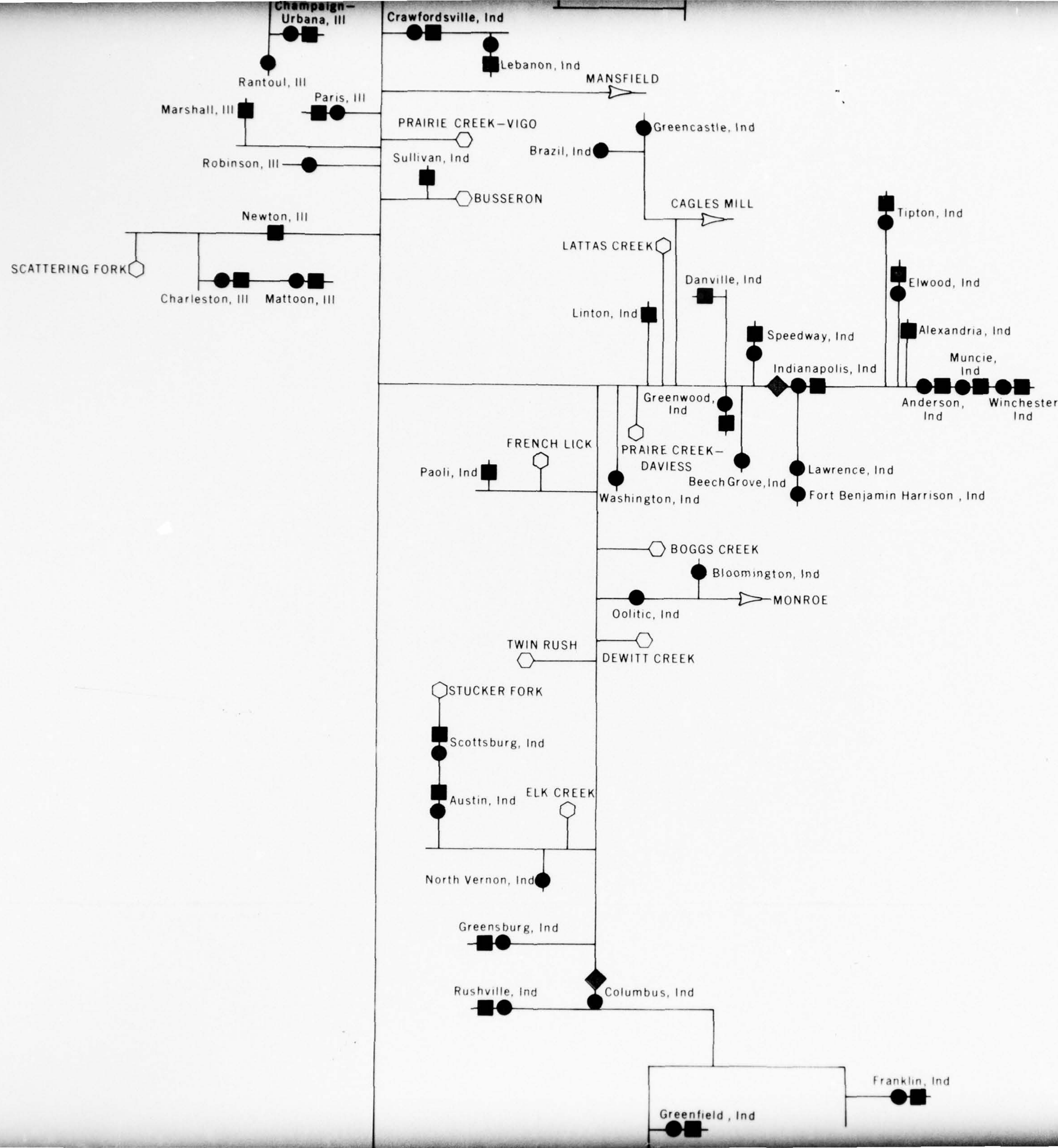
RESERVOIRS AND WATERSHED PROJECTS
IN GOING PROGRAM, AND POTENTIALS

CORPS OF ENGINEERS
APPENDIX K

U.S. ARMY OHIO RIVER DIVISION
FIGURE WA-1



UPPER WABASH
Bluffton, Ind
HUNTINGTON
Huntington, Ind
SALAMONIE
Portland, Ind
Wabash, Ind
MISSISSINEWA
Marion, Ind
Hartford City
Union City, Ind
MILL CREEK–FULTON
Peru, Ind
BACHELOR RUN
Warsaw, Ind
KICKAPOO CREEK
Kokomo, Ind
Danville, Ill
LITTLE WEA CREEK
Frankfort, Ind
Champaign–Urbana, Ill
Crawfordsville, Ind
Lebanon, Ind
Rantoul, Ill
MANSFIELD
Paris, Ill
Marshall, Ill
PRAIRIE CREEK–VIGO
Greencastle, Ind
Brazil, Ind
Robinson, Ill
Sullivan, Ind
BUSSERON
CAGLES MILL
Tipton, Ind
Newton, Ill
LATTAS CREEK
SCATTERING FORK
Danville, Ind
Elwood, Ind
Charleston, Ill
Mattoon, Ill
Linton, Ind
Alexandria, Ind
Speedway, Ind
Indianapolis, Ind
Muncie, Ind
Greenwood, Ind
Anderson, Ind
Winchester, Ind
LEGEND
PROJECTS IN GOING PROGRAM
Corps of Engineers Reservoir
Watershed Project
PROBLEM AREAS
Water supply
Water Quality
Major Flood Damage



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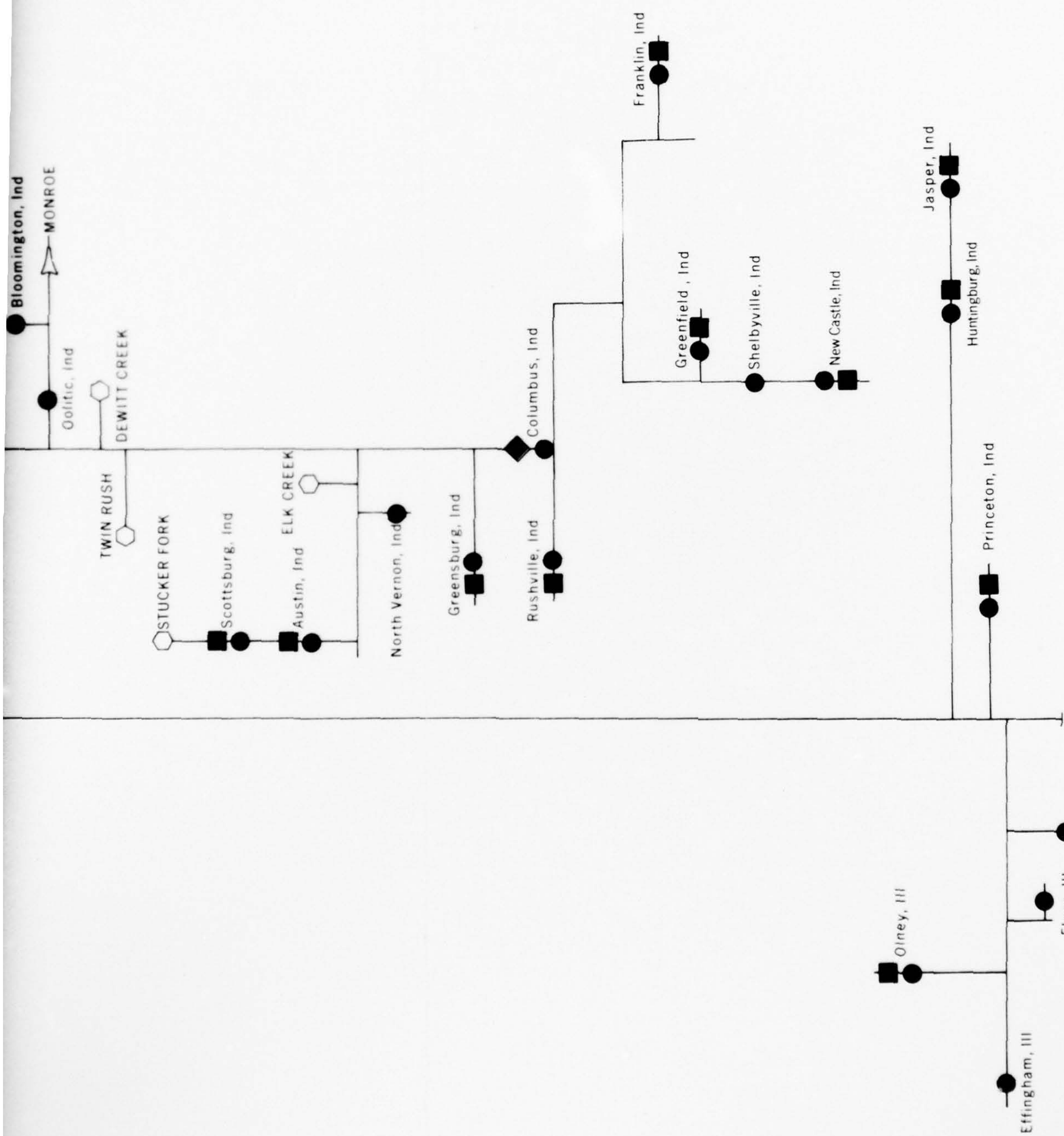

OHIO RIVER BASIN COMPREHENSIVE SURVEY

WABASH SUBBASIN
ANALYSIS SCHEMATIC

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION
APPENDIX K FIGURE WA-2

3

CUMBERLAND

1. Planning Environment. The Cumberland River subbasin, situated in the most southerly portion of the Ohio study region, contains 17,920 square miles, or 11 percent of the land in the study area. The subbasin has a unique east-west alignment, being for the most part almost parallel to the Ohio River. The central section, which comprises about 60 percent of the total subbasin area, lies in north central Tennessee. The eastern and western sections of the subbasin lie in southeastern and southwestern Kentucky, respectively. The topography is rolling to rugged with elevations ranging from 4,150 feet above mean sea level in the Cumberland Mountains to 302 feet at the confluence of the Cumberland and Ohio Rivers. Much of the land is heavily forested. Due to the southerly location, the growing season is the longest in the Ohio Basin study area.

The subbasin has a history of recurring, heavy, widespread rains and summer thunderstorms with intense rainfall. Runoff has been greater than the average for the Ohio Basin, and flooding occurs frequently in some locations. In contrast, extended droughts, although infrequent, have caused severe crop losses and other problems associated with acute water shortages. The water resources of the Cumberland subbasin are the most highly developed of all subbasins in the study area. Storage capacity and surface area of reservoirs are greater than for any other subbasin. Flow regulation on the Cumberland River has been very beneficial in controlling flows on the Mississippi River as well as the lower Ohio.

The Cumberland subbasin has about six percent of the population and labor force within the Ohio Basin study area, and produces about four percent of the industrial output. Nashville is the major industrial and commercial center of the Cumberland subbasin and the largest metropolitan center in the southern part of the Ohio Basin study area. Employment in apparel manufacturing is the highest in the Ohio Basin study area; agriculture and lumber and furniture manufacturing rank second in employment in relation to the other subbasins. Each sector is expected to hold its relative position in the future. Within the subbasin, agricultural employment is expected to decline, as is typical throughout the Ohio Basin, and manufacturing to increase rapidly. Projective economic studies indicate that the general economy of the Cumberland subbasin will continue to grow at a greater rate than that of the overall Ohio Basin. The greatest dollar gain will be in manufacturing which is projected to increase 1960 output over sixfold by 2020. Largest output is expected to be in food, machinery, apparel, and tobacco and leather products.

2. Demand for Water and Related Functions and Services. In contrast to the situation generally existent at other large metropolitan locations, there are no significant problems dependent on water resource development for solution predicted for the future in the Nashville metropolitan area. This is due primarily to the extensive developments provided upstream of the Nashville area. Unsatisfied demands for water

supply, water quality improvement, flood protection and other water related functions and services are widely distributed at other locations in the subbasin.

Nineteen urban locations with immediate water quality problems resulting from organic pollution have been identified. One water supply problem area exists and it is expected that development of an additional source of supply will be required at 14 more locations in the future. Over half of these are at the locations with water quality problems.

Flooding is still a problem at many locations, particularly in upstream watershed areas. There are four urban locations in the upper reaches of the basin where average annual damages exceed $50,000.

The availability of low-cost transportation for the transport of bulk commodities is highly important to the economy of the Cumberland subbasin. Principal commodities transported on the Cumberland waterway are petroleum products and stone, sand, and gravel, with nearly all of this inbound and upbound to contiguous areas in Kentucky and Tennessee. Iron and steel products and chemicals and sulfur are other commodities of significance imported by water into the area. The modern waterway that will be provided upon completion of the going program for navigation will be capable of handling projected future traffic on the lower Cumberland River. However, farther upstream, there is a demand for water transport of coal, timber, gasoline, and shale. Extension of the navigation system to the mouth of the Laurel River at the upper end of Lake Cumberland would satisfy this demand.

Demands for outdoor water-based recreation are currently being supplied. However, if predicted future recreational desires are to be satisfied, particularly those generated in areas outside the subbasin but within its zone of influence, further development of resources and additional facilities will be required.

a. Going Program Accomplishment. Summary data for projects in the going program are given in Appendix K, tables 15 through 21. See figure CU-1 for location.

Approximately 90 percent of the water withdrawal requirements in the Cumberland subbasin have been supplied from surface water sources. Seventy percent of the municipal and industrial water requirement, concentrated principally in the highly industrialized Nashville area, is taken from the Cumberland River. Rural areas in the subbasin are served primarily from ground water sources. Except for one known location, Franklin, Tennessee, which is in immediate need of an additional source of supply, water withdrawal requirements have been adequately served.

As of July 1965, three Federal multiple-purpose reservoirs with flood

control as one of the primary functions were complete and in operation and two were under construction. All five projects have power installations with storage reserved for power regulation, and all provide important recreation benefits. Also, Barkley, one of the projects under construction, is the site of the lowermost navigation lock on the Cumberland River waterway. These projects provide control of a major portion of the Cumberland River drainage. Of the total storage capacity of 12.6 million acre-feet, 5 million acre-feet of reservoir space is reserved for the control of flood flows. In addition, three major and one small local protection projects were complete and two major local protection projects were under construction; these would provide 12.9 miles of levees, floodwalls and channel improvements. Six upstream watershed projects, covering 306 square miles and containing 18,580 acre-feet of flood storage capacity and 48 miles of channel improvements for control of flood flows, had been authorized. The foregoing projects would prevent $5.34 million or about 50 percent of the potential average annual damages in the subbasin under 1965 conditions of flood plain development. About 95 percent of the damages prevented would be in downstream areas.

The navigable waterway on the lower Cumberland River, when complete, will be provided by four modern dam-lock structures and will extend 381 miles with minimum 9-foot depth from the Ohio River to Celina, Tennessee. Cordell Hull lock and dam, in addition to Barkley, was under construction in July 1965. Barkley Canal was also under construction. The canal, 1.75 miles long with an 11-foot project depth, connects Lake Barkley on the Cumberland with Kentucky Lake on the Tennessee River. Barkley lock and dam and Barkley Canal were completed by September 1966. The practical physical capacity of the Cumberland waterway with completion of Cordell Hull, the uppermost project, will be about 3.8 billion ton-miles annually.

As inventoried in 1963, approximately 63 percent, 946 megawatts, of the hydroelectric power capacity, existing or under construction in the Ohio Basin study area, was located in the Cumberland subbasin. Eight plants with a total of 853 megawatts installed capacity are located at the Corps of Engineers navigation and flood control projects accounted for in previous paragraphs. Two are single purpose power projects; one, Laurel, under construction, is a Corps of Engineers project with 61 megawatts and the other, Great Falls, is an existing Tennessee Valley Authority project with 32 megawatts. Much of the capacity is utilized in the TVA power system.

Land management and conservation programs have been in effect for some time. Legislative enactments have been put into effect and other efforts made to reclaim strip mined areas and control mine drainage and other pollution of streams. Development and management programs have been put into effect to improve land cover and provide facilities

for outdoor recreation, hunting and fishing throughout the subbasin. Land treatment and management in the six authorized upstream watershed projects will aid in retarding runoff and controlling erosion and enhance other efforts in upstream areas.

Total land and water acreage set aside for recreation pursuits, as inventoried in 1960, was 663,000 acrea. The amount of water for recreation, approximately 135,000 acres, exceeded the total of all other water areas inventoried in the Ohio Basin study area. Five Federal projects accounted for 126,000 acres of the recreational waters. In addition to the reservoirs; four National Park Service areas; 24 state parks, forests and fish and game areas; and portions of the Cumberland National Forest offered recreational opportunity. In 1960, water related recreational activity amounted to 12.4 million outdoor recreation days, and 3.5 million angler days and 1.2 million hunter days of fishing and hunting, respectively.

b. Future Demand. Base year and projected increases in demand for water and related functions and services which will intensify demand for further use, development and management of water and related land resources are shown in table CU-1.

Water withdrawal demands are projected to total about 2.1 billion gallons per day in 1980 and then decline to 1.7 billion gallons per day by 2020. The lesser demand in 2020 is due to the projected reduction in water withdrawn for electric power cooling purposes. Over 90 percent of the 1.25 billion gallons per day increase in withdrawal demand projected for 1980 is for electric power cooling; by 2020, only 35 percent of the projected increase will be for this purpose. By 2020, municipal and industrial water demands are projected to be over five times the amount withdrawn in 1960; withdrawals in 2020 will be about 35 percent of total withdrawals as opposed to 13 percent of the total in 1960.

By 2020, organic waste loads are projected to total 4.5 times those existent in 1960. Additional streamflow will be required to provide waste assimilation capacity within acceptable standards of quality primarily in areas tributary to the Cumberland River. The Cumberland River has sufficient waste assimilation capacity, particularly in the lower reaches, to absorb projected organic waste effluent provided waste treatment capacity is maintained to remove at least 85 percent of the BOD entering treatment plants.

Residual average annual damages after completion of the going program for flood control would be about $4.8 million. About 90 percent of the potential damages would be in upstream areas. By 2020, unless additional protective works and management actions are taken to prevent them, total potential average annual damages are estimated to exceed

$10 million with projected conditions of flood plain development.

Traffic on the Cumberland waterway amounted to 453 million ton-miles in 1965. This was on the 308-mile reach from the Ohio River to Carthage, Tennessee. By 2020, demand for waterborne transport is expected to reach 3 billion ton-miles on the 381 miles which will comprise the waterway upon completion of Cordell Hull lock and dam. Estimated demand in the upper Cumberland for which a waterway extention is being considered is 200 million ton-miles by 2020. Construction of a lock at the authorized Celina Dam and transfer facilities at Wolf Creek would be required to accommodate this traffic.

In the past, a surplus of electric power has been generated in the Cumberland subbasin and exported to other areas. However, by 2020, it is estimated that in the range of 75 to 80 percent of the energy required in support of industrial expansion and general growth of the economy will be imported. Additional hydroelectric power, particularly peaking capacity where found economically feasible, could be utilized in conjunction with fossil fuel and nuclear baseload plants.

Land area requiring treatment and management for efficient use is projected to increase 5.2 million acres by 2020. Most of the agricultural land in the subbasin is such that drainage is not required. A small fraction of the total, 63,000 acres, was drained as inventoried in 1960. The amount of land that can be economically drained by 2020 is projected to increase only an additional 139,000 acres. The amount of irrigated acreage is likewise small. In 1960, only 3,000 acres received supplemental water for irrigation. The increase projected for 2020 is only 13,900 acres.

By 2020, the demand for outdoor recreation is predicted to increase nearly five times the activity reached in 1960, totaling approximately 61 million recreation days. This demand, in conjunction with increased hunting and fishing pressure, will require full utilization of water and lands affiliated with water resource development.

3. Resource Availability. Reservoirs existent and under construction in July 1965 will provide control of much of the surface flows in the Cumberland subbasin. The remaining overall development potential is more than ample to satisfy development requirements projected for 2020. Surface runoff is high and, in general, reservoir sites are plentiful. There is less potential for future ground water development than other areas in the Ohio River Basin; most of the highest yielding sources, the large limestone springs, are already being used. However, yields adequate for small municipal and industrial supplies are available in large areas of the subbasin.

Nine potential multiple-purpose reservoirs with a total of over 5.3 million acre-feet of storage capacity for flood control and other purposes have been investigated in some detail and are considered feasible. These reservoirs would add significantly to outdoor recreational opportunity in the subbasin. Potential upstream watershed project development includes 45 projects covering 3,914 square miles with 258 sites having a total potential storage capacity of about 2.4 million acre-feet for sediment control, floodwater storage and other uses.

The hydroelectric power potential has not been fully investigated; however, in consideration of the rugged topography and relatively high heads that could be developed in some of the upstream areas, this might be substantial. Seven undeveloped hydroelectric power sites with potential installations totaling 864 megawatts have been identified. Over half of the capacity, 480 megawatts, is proposed in conjunction with the potential Devils Jumps multiple-purpose reservoir site on the Big South Fork Cumberland River in Kentucky; 108 megawatts would be installed at the proposed Celina project on the Cumberland River and 18 megawatts at the Three Islands flood control project on the Harpeth River in Tennessee. The remaining 258 megawatts of capacity is associated with four sites located on streams in Kentucky, the largest being a potential pumped storage project of 135 megawatts on Jellico Creek. Other opportunities for pumped storage developments should be available in the basin.

The Cumberland subbasin is richly endowed with resources that may be utilized for outdoor recreation development and fish and wildlife management. There are many scenic and wooded areas and the topography is generally favorable for the creation of attractive recreational areas. Considering the wealth of potential recreation resources, the Cumberland is in a favorable position to help alleviate needs originating in metropolitan centers beyond the immediate zone of influence. Week-end and vacation-type facilities could be provided to help meet needs as far away as St. Louis, Chicago, Cincinnati and Indianapolis.

4. Assessment of Resource Development Requirements. Principal water supply, water quality and flood problem areas, together with reservoirs and upstream watershed projects in the going program of development, and those identified as potential future projects, are shown on the subbasin map, figure CU-1. Summary data for identified potential projects are given in Appendix K, tables 24 through 28. The relationship of problem areas and projects in the going program is shown schematically in figure CU-2, and key data relating to problem areas are given in table CU-2. The schematic diagram was used for general orientation in analyzing problems and needs and establishing development requirements for streamflow control. An accounting of

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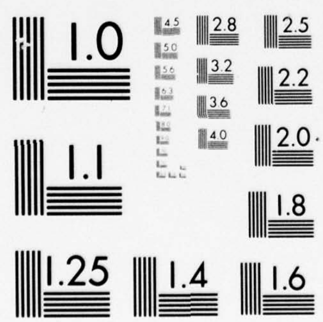


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

storage capacity for streamflow control is given in table CU-3. Results of the subbasin assessment to determine the magnitude and costs of resource development required to satisfy projected demands for water and related functions and services are summarized in table CU-4.

a. Requirements to be Furnished by Identified Resource Potential. Analysis of demands for water and related functions and services and of the means whereby these demands can be satisfied indicates that to solve water supply, water quality and flood problems, development of additional storage capacity for streamflow control will be required; also local protection projects and channel improvements will be required in several locations, either singly or in combination with streamflow regulation to cope best with the flood problems.

Total storage capacity required to provide for water quality, water withdrawals and flood control is estimated to be over 1.8 million acre-feet in addition to the amount that will be made available upon completion of the going program. By 2020, approximately 457,000 acre-feet of this amount will be required to provide for low flow requirements and 1.38 million acre-feet for control of flood flows. The combined requirement can be met with about 1.5 million acre-feet of reservoir space which includes use of about 20 percent of the flood storage space in identified reservoirs on a joint use basis.

About 402,000 acre-feet of the storage capacity required to supplement streamflows can be provided in identified potential reservoirs, including those in upstream watershed projects. This includes the joint use of 275,000 acre-feet of flood control space. In numerous upstream areas, due to the potential magnitude of organic waste loads in relation to stream assimilation capacity that can be provided, advanced waste treatment may have to be adopted in addition to storage to sustain satisfactory stream quality. Storage capacity provisions for streamflow supplementation are the added amounts to satisfy demands beyond the capability of available surface flows and ground water sources. The ground water potential is considered adequate to provide 43 million gallons per day by 2020 in addition to the pumpage inventoried in 1960.

About 1.4 million acre-feet of reservoir capacity, including 356,000 acre-feet associated with upstream watershed projects can be provided by identified resource potential for control of flood flows. In addition, one major and 16 small local protection projects that would assist in providing flood protection and 775 miles of channel improvement in potential upstream watershed projects are identified. An effective flood plain management program can aid in maintaining the high degree of flood damage reduction provided by existing and proposed protection.

Waterborne traffic on the Cumberland River has been growing steadily with the industrial expansion in the subbasin. The apparent physical

capability of the 381-mile reach of waterway on the lower Cumberland will be in excess of 2020 demand. However, to accommodate demand for waterborne transport in upriver areas, an extension of the waterway will be required. This would be accomplished by construction of a lock at the authorized Celina Dam which would extend the 9-foot-depth canalized waterway 80 miles upstream to the existing Wolf Creek Dam, and providing a cargo lift or lock at that dam. The provision of either facility at the dam would extend the navigation system another 90 miles, via Lake Cumberland to the mouth of the Laurel River. Later deepening of the waterway on the lower Cumberland, concurrently with the provision of greater depth in the Ohio River, would be undertaken to enhance the efficiency of the transport system.

The identified hydroelectric power potential of 864 megawatts installed capacity would be useable prior to 1980 to meet a portion of the growing Ohio Basin power requirements. Inclusion of the power potential as an element of water resource development is based on judgment that the installation will prove to be desirable and economically feasible in comparison to alternative sources of power supply.

The total area in potentially feasible upstream watershed projects is about 2.5 million acres. Of this amount it is estimated that about 1.45 million acres of cropland, pasture and woodland will require treatment and management to enhance land productivity and serve other beneficial purposes. Retardation of runoff, control of erosion and reduction of sediment transport to streams are important considerations.

The construction of potential reservoirs forms the focal point of development designed to meet future water oriented recreation demands. These reservoirs and developments, including upstream watershed projects, will provide potential opportunities for nearly 27 million outdoor recreation days annually if access and attractive facilities are made available.

b. Remaining Requirements. The 55,000 acre-feet of additional storage capacity for supplementing streamflows is required to provide quality control and furnish water for withdrawal and use. It includes water required in areas not identified by specific location of need and that required to provide stream regulation in several identified areas of need, but for which storage developments are not identified.

Storage capacity that can be made available in identified potential projects is sufficient to provide for flood control requirements in the subbasin. This capacity also would contribute to flood stage reduction on the Ohio River.

CUMBERLAND

The extent to which demand for outdoor recreation, fishing and hunting opportunity could be satisfied by water resource developments beyond that provided by identified potentials has not been defined. It appears that to satisfy future recreation demands generated in the subbasin and to take advantage of the opportunity to serve other areas, considerable additional development specifically for recreation will be required.

Remaining land treatment and management requirements are associated with general land base outside watershed projects with the exception that lands irrigated or drained may be located in or outside of watershed projects. By the year 2020, approximately 3.8 million acres of cropland, pastureland and woodland would be subject to treatment and management measures. These lands are accounted for in the general inventory of requirements but are not identified by specific location.

TABLE CU-1

CUMBERLAND SUBBASIN
DEMAND FOR WATER AND RELATED FUNCTIONS AND SERVICES

	Unit	Base Year Amount	Projected Increase[1] 1980	Projected Increase[1] 2020
Water Withdrawal				
Municipal and Industrial[2]	Million Gallons Per Day	112.1	86.0	471.5
Electric Power Cooling	Million Gallons Per Day	703	1,137	287
Rural Communities	Million Gallons Per Day	37.1	24.1	55.8
Rural Domestic and Livestock	Million Gallons Per Day	16.70	0	0.99
Irrigation[3]	Million Gallons Per Day	1.7	1.2	6.3
Stream Assimilation of Organic Waste Effluent[4]	1,000 Population Equivalents	109.5	69.0	380.0
Flood Damage Prevention[5]	Million Dollars Annually	5.34	6.97	10.24
Waterway Freight Movement[6]	Million Ton-Miles Annually	3,800	20	200
Hydroelectric Power - Installed Capacity	Megawatts	945.9	(Assessed on a basin-wide basis)	
Outdoor Recreation	Million Recreation Days	12.4	10.8	48.7
Sport Fishing	Million Angler Days	3.50	1.90[7]	4.90[7]
Hunting	Million Hunter Days	1.20	0.30[7]	0.50[7]
Commercial Fishing			(Assessed on a basin-wide basis)	
Land Treatment and Management	1,000 Acres	196	1,674	5,247
Drainage	1,000 Acres	63	103	139
Irrigation (Land Area)	1,000 Acres	3.0	2.3	13.9

NOTES: (1) Base year amounts plus projected increase equals gross demands.

(2) Mining industry water requirements not included; assessed on a basin-wide basis.

(3) Withdrawal shown is for average year; drought year may be 45 percent higher.

(4) Residual biochemical oxygen demand after 85 percent waste removal by treatment.

(5) The dollar amounts (1980 and 2020) are indices to the magnitude of the problem and the protection measures required to reduce the potential damaging effects of floods.

(6) An index to the canalization and waterway facilities required to accommodate the transport of waterborne freight.

(7) Net requirements.

TABLE CU-2

CUMBERLAND SUBBASIN
PRINCIPAL CONSIDERATIONS IN DETERMINING STORAGE CAPACITY REQUIREMENTS
FOR CONTROL OF STREAMFLOW

A. SUPPLEMENTAL STREAMFLOW REQUIRED AT KEY LOCATIONS TO CONTROL WATER QUALITY (CFS).

Problem Area(1)	Stream	Required Flow(2) 1980	Required Flow(2) 2020	Flow Provided by Going Program	Supplemental Flow Required 1980	Supplemental Flow Required 2020
Lynch, Ky	Looney Creek	5	10	0	5	10
Harlan, Ky	Martins Fork	5	10	0	5	10
Cumberland, Ky	Poor Fork	5	10	0	5	10
Middlesboro, Ky	Yellow Creek	12	30	3	9	27
London, Ky	Whitley Branch	7	17	0	7	17
Corbin, Ky	Lynn Camp Creek	10	24	0	10	24
Somerset, Ky	Sinking Creek	23	58	0	23	58
Monticello, Ky	Elk Spring Creek	7	20	0	7	20
Jamestown, Tenn	Rockcastle Creek	7	15	3	4	12
Livingston, Tenn	Town Branch	10	15	1	9	14
Cookeville, Tenn	Short Creek	20	60	4	16	56
Lebanon, Tenn	Sinking Creek	26	65	4	22	61
Gallatin, Tenn	Town Creek	28	53	4	24	49
Woodbury, Tenn	East Fork Stones River	10	15	1	9	14
Murfreesboro, Tenn	West Fork Stones River	30	90	1	29	89
Franklin, Tenn	West Fork Harpeth River	15	36	1	14	35
Springfield, Tenn	Sulphur Fork Creek	13	30	4	9	26
Hopkinsville, Ky	North Fork Little River	30	90	3	27	87
Princeton, Ky	Eddy Creek	10	15	1	9	14

B. WATER REQUIRED TO SATISFY DEMANDS FOR WITHDRAWAL AND USE (IN ADDITION TO THAT PROVIDED IN BASE YEAR) (MGD).

Item	1980	2020
1. Total withdrawal(3)	1,248	822
2. To be provided by groundwater	8	43
3. Total consumptive use	32	76

C. FLOOD DAMAGE AREAS.

Location	Residual Damages(4) (Millions Dollars)	
1. Upstream areas	4.31	
2. Major urban areas(1)	0.28	
Pineville, Ky, Straight Creek Harlan, Ky, Martins Fork & Clover Fork Barbourville, Ky, Cumberland River Loyall, Baxter, Ky, Cumberland River		
3. Other flood plain areas	0.24	
4. Total subbasin	4.83	Projected to 6.97 in 1980 and 10.24 in 2020.

NOTES: (1) See figure CU-1 for geographic location of principal problem areas and figure CU-2 for schematic relationship.

(2) Streamflow required to maintain a minimum of 4 parts per million of dissolved oxygen.

(3) Water required to satisfy municipal and industrial, electric power cooling, rural community, rural domestic and livestock, and irrigation demands.

(4) Estimated average annual damages with the 1965 flood control program completed (1965 constant dollars).

TABLE CU-3

CUMBERLAND SUBBASIN
ACCOUNTING OF STORAGE CAPACITY FOR STREAMFLOW CONTROL
(IN ADDITION TO THAT PROVIDED IN THE GOING PROGRAM)

	Time Period 1980	Time Period 2020
	Storage (1,000 Ac Ft)	
A. WATER QUALITY CONTROL.		
1. Storage required (1)	137.4	342.3
2. Storage provided in identified potential sites	11.2	11.2
3. Additional storage required	126.2	331.1
B. WATER WITHDRAWALS.		
1. Storage required	27.5	115.1
C. FLOOD CONTROL.		
1. Subbasin and Ohio River control requirement	393.1	1,378.5
2. Storage provided in identified potential sites	393.1	1,378.5
a. for solving localized problems	(119.0)	(356.1)
b. effective in controlling both subbasin and Ohio River flows	(274.1)	(1,022.4)
3. Additional storage required (2)	0	0
D. TOTAL STORAGE REQUIREMENT.		
1. Water quality control, water withdrawals, and flood control	558.0	1,835.9
2. Available in identified potential sites (3)	426.4	1,504.8
3. Joint use storage	78.6	275.7
4. Additional storage required (4)	53.0	55.4

NOTES: (1) Storage capacity required to provide supplemental flows at key urban locations and rural communities in upstream watershed areas.

(2) Remaining Cumberland subbasin share of storage required to reduce the Ohio River Basin Standard Project Flood to the maximum flood stage of record.

(3) See figure CU-1.

(4) Terrain indicates storage sites are potentially available.

TABLE CU-4

CUMBERLAND SUBBASIN
SUMMARY ASSESSMENT OF RESOURCE DEVELOPMENT REQUIREMENTS

			Additional Requirement (1)			
			1980		2020 (Accumulative)	
Program Elements	Unit	Provided in Going Program	Amount	Capital Cost ($1,000)	Amount	Capital Cost ($1,000)
PART 1. TO BE FURNISHED BY IDENTIFIED RESOURCE POTENTIAL WITHIN SUBBASIN.						
A. Streamflow Control and In-Stream Use						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	3,663.3	33.3	4,200	126.3	25,700
2. Control of Flood Flows						
a. reservoir and detention storage	1,000 Ac Ft	5,049.6	393.1	99,900	1,378.5	351,000
b. local protection projects	Miles	12.9	1.2	800	1.2	800
c. channel improvement	Miles	48	259	17,300	775	51,700
3. Navigable Waterway						
a. improvement to existing waterway	Miles of Channel	380	0	0	0	0
b. new waterway	Miles of Channel	-	170	14,000	170	14,000
c. channel deepening to 12 feet	Miles of Channel	-	0	0	216	11,000
4. Hydroelectric Power - Installed Capacity	Megawatts	945.9	864	97,200	(Assessed on a Basin-wide Basis)	
B. Related Programs						
1. Outdoor Recreation (2) (3)	Million Recreation Days	12.4	5.8	18,800	26.8	89,100
2. Watershed Project Land Treatment and Management (4)	1,000 Acres	196	485.5	12,100	1,453.5	36,300
	COSTS - PART 1			264,300		579,600
PART 2. REMAINING REQUIREMENTS.						
A. Streamflow Control and In-Stream Use (5)						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	-	53.0	13,500	55.4	14,100
2. Storage for Control of Flood Flows	1,000 Ac Ft	-	0	0	0	0
3. Hydroelectric Power				(Assessed on a Basin-wide Basis)		
B. Related Programs						
1. Outdoor Recreation (2) (6)	Million Recreation Days	-	5.0	15,700	21.9	71,600
2. Fish and Wildlife						
a. sport fishing (2) (6)	Million Angler Days	3.50	1.90	6,600	4.90	17,200
b. hunting (2) (6)	Million Hunter Days	1.20	0.30	1,000	0.50	1,800
c. commercial fishery				(Assessed on a Basin-wide Basis)		
C. Land Treatment and Management						
1. Lands Outside Watershed Projects	1,000 Acres	-	1,188.1	29,700	3,793.0	94,800
2. Irrigation (Acres to be Irrigated)	1,000 Acres	3.0	2.3	200	13.9	1,300
3. Drainage	1,000 Acres	63	85.4	11,200	137.7	18,000
	COSTS - PART 2			77,900		218,800
	TOTAL COSTS - (PARTS 1 AND 2)			342,200		798,400

NOTES:
(1) Requirement in addition to that provided by going development programs.

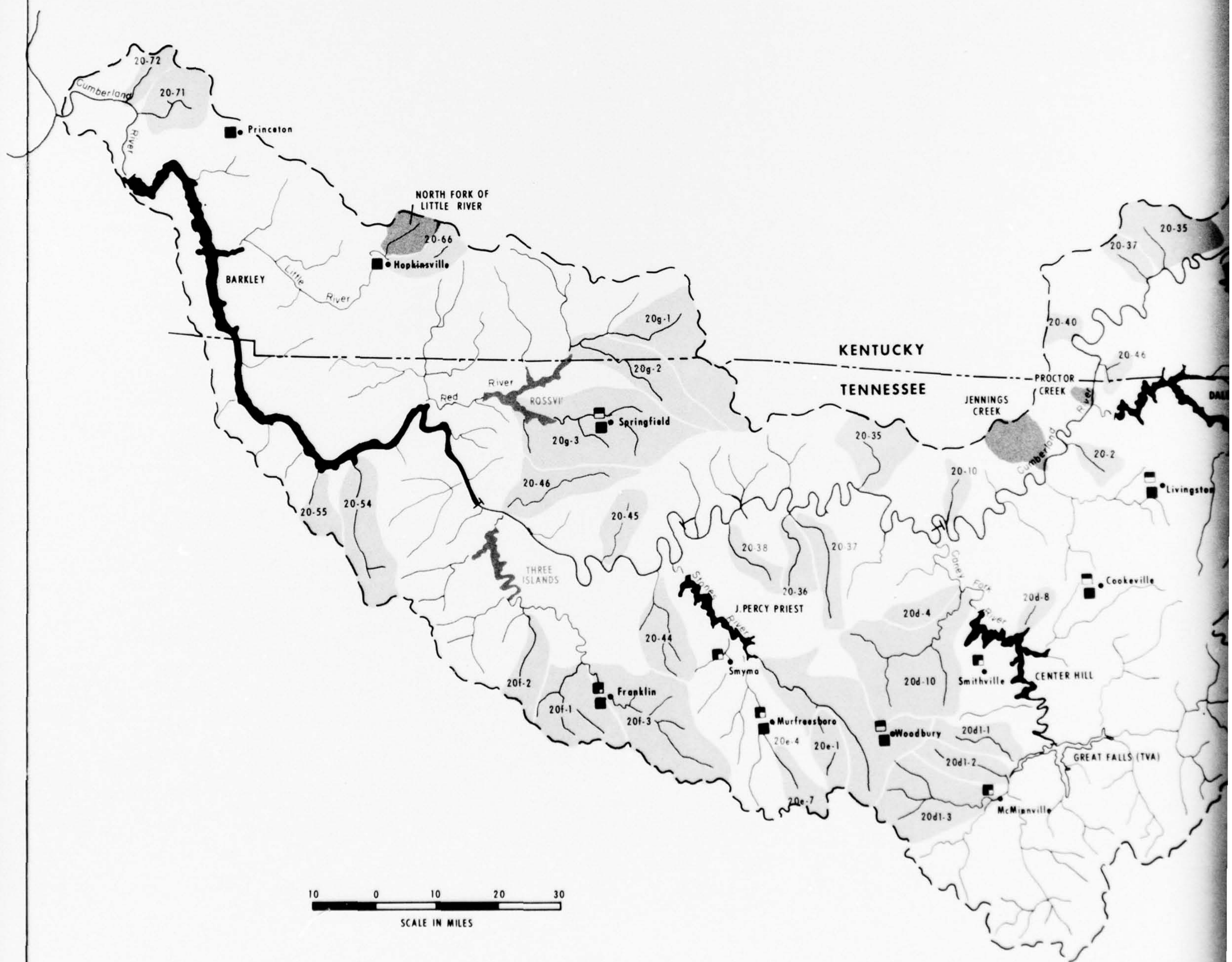
(2) Costs shown are for initial facilities and such measures as may be required to implement the program and do not include water and related land cost. Base year 1960.

(3) The number of outdoor recreation days shown include some sport fishing and hunting which could not be separately accounted for in available data.

(4) Land area and costs shown are for total land treatment and management requirements in watershed projects and cover both water resource development related and other lands.

(5) Specific sites to provide storage capacity for streamflow control are not identified; however, favorable storage sites are potentially available.

(6) Because of population and resource distributions, remaining subbasin requirements for outdoor recreation, sport fishing and hunting not satisfied by water resource developments may require a trade off with adjacent subbasins or satisfied by other means.



20-72
20-71
Cumberland
River
Princeton
NORTH FORK OF
LITTLE RIVER
20-66
Hopkinsville
BARKLEY
Little
River
20g-1
KENTUCKY
TENNESSEE
20g-2
River
Red
ROSSVI
Springfield
20g-3
20-46
20-45
20-55
20-54
THREE
ISLANDS
20-35
20-37
20-40
20-46
PROCTOR
CREEK
JENNINGS
CREEK
20-35
20-2
20-10
Livingston
20-38
20-37
20-36
Caney
Fork
River
Cookeville
20d-8
J. PERCY PRIEST
20d-4
20-44
Smyrna
20d-10
Smithville
CENTER HILL
20f-2
Franklin
20f-1
20f-3
Murfreesboro
20e-4
20e-1
Woodbury
20d1-1
20d1-2
GREAT FALLS (TVA)
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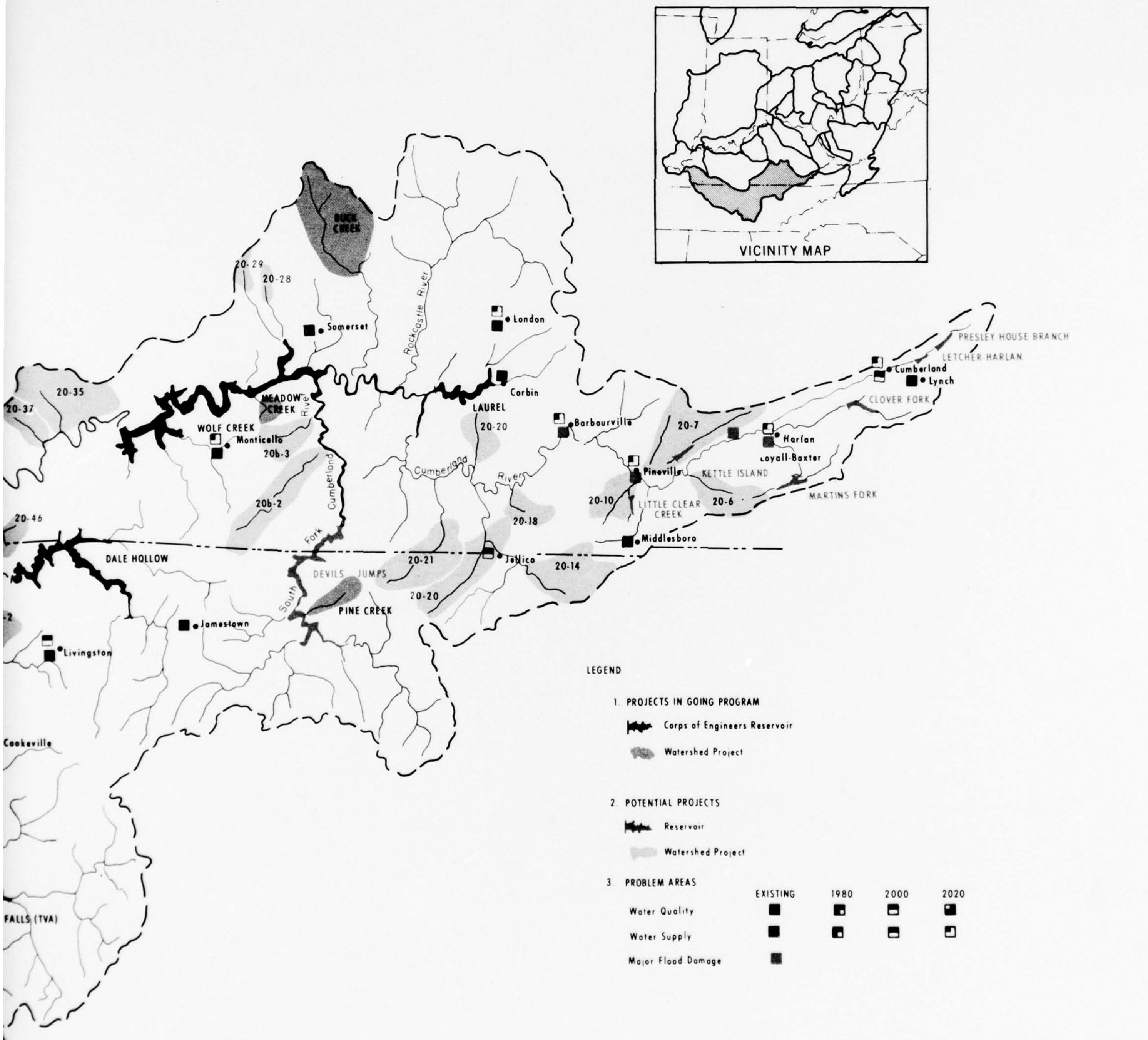
20d1-3
McMinnville
10 0 10 20 30
SCALE IN MILES



OHIO RIVER BASIN COMPREHENSIVE SURVEY

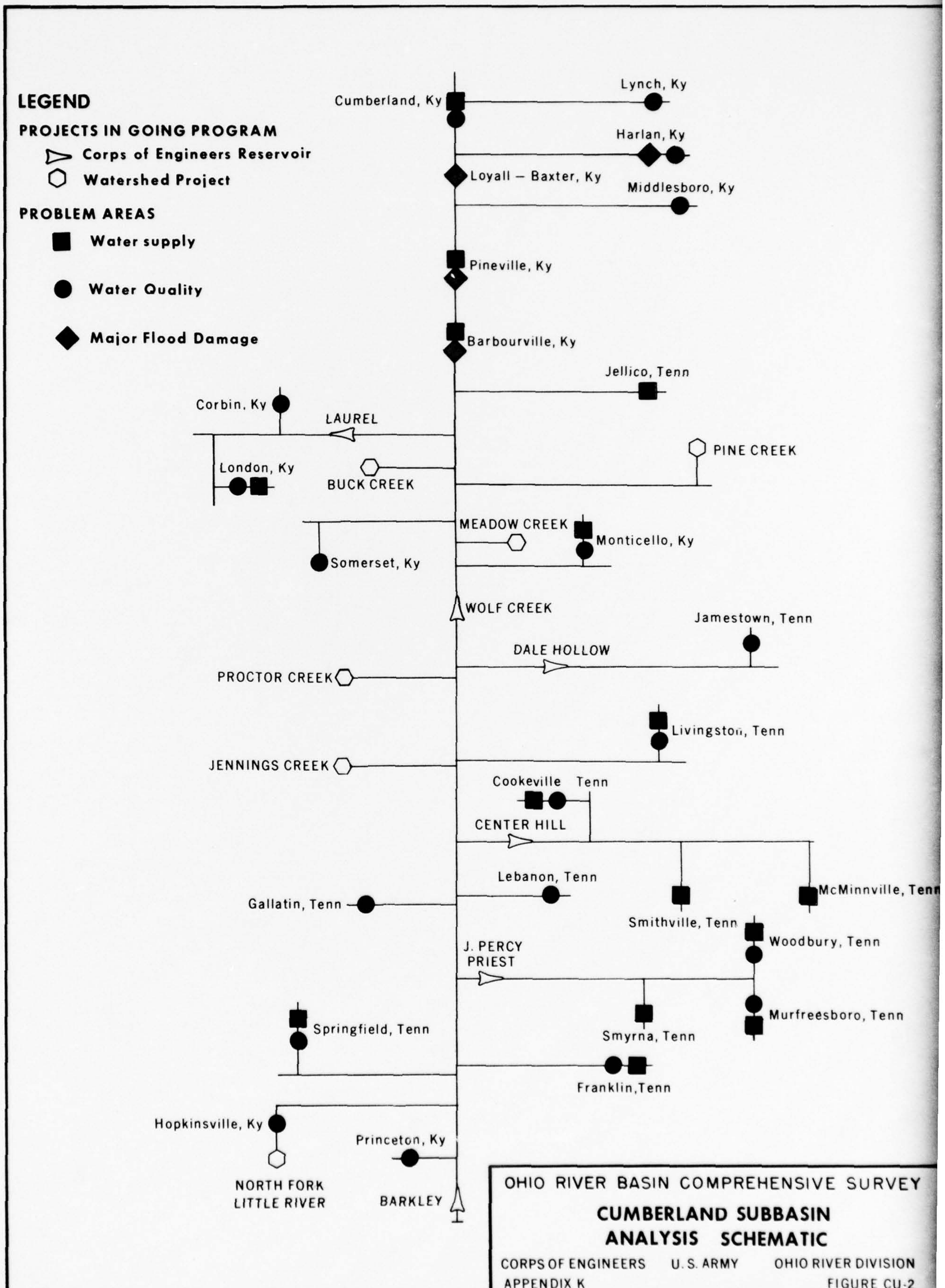
CUMBERLAND SUBBASIN

PRINCIPAL
WATER SUPPLY, WATER QUALITY AND FLOOD
PROBLEMS

RESERVOIRS AND WATERSHED PROJECTS
IN GOING PROGRAM, AND POTENTIALS

CORPS OF ENGINEERS
APPENDIX K

U.S. ARMY OHIO RIVER DIVISION
FIGURE CU-1



OHIO RIVER BASIN COMPREHENSIVE SURVEY

CUMBERLAND SUBBASIN ANALYSIS SCHEMATIC

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE CU-2

OHIO RIVER AND MINOR TRIBUTARIES

1. Planning Environment. - The Monongahela and Allegheny Rivers meet at Pittsburgh, Pennsylvania, to form the Ohio River. The Ohio River then flows in a southwesterly direction for 981 miles to the Mississippi River at Cairo, Illinois, generally bisecting the Ohio Basin. The Ohio River drains a total of 203,940 square miles, but only 163 thousand square miles are included in the study area. The Tennessee River Basin, for which a separate comprehensive Type I study will be made, has been excluded.

The tributary drainage area flanking the Ohio River averages 10 to 15 miles in width on each side for a total of 24,800 square miles. The topography of the area varies greatly. Near the mouth of the Ohio River, the land is flat to rolling, while in the vicinity of Pittsburgh the terrain is rugged. Nearly 4,000 square miles of the land is in flood plain. About two-thirds of this is subject to inundation by Ohio River flood flows.

The Ohio River played an important role in the early development of the nation. Settlers used the river as a principal means of access to the interior. This early waterway route to the west developed rapidly and today is a major artery for waterborne transport of goods. The area along the Ohio River, including the minor tributaries, contains about one-third of the basin's population. Major metropolitan concentrations are located at Pittsburgh, Pennsylvania; Huntington, West Virginia; Cincinnati, Ohio, Louisville, Kentucky; and Evansville, Indiana. In between these locations, the banks are lined with industrial complexes and important smaller communities.

Fifty percent of the primary metals produced in the Ohio Basin and 40 percent of the fabricated metals, chemicals, and food processing output occurs along the Ohio River. The river's importance continues to grow each year and in the period from 1950 to 1965, over 25 billion dollars was invested in industry in the counties along the Ohio River and its navigable tributaries. Over 25 percent of this investment was made in the primary metals and electric power industries. Raw materials and goods produced range from bulk items such as sand, gravel, iron, steel and agricultural products to highly sophisticated electronic equipment. These items range in value from pennies to hundreds of dollars per pound. Services provided play an important role in the economy, value being measured in several billion dollars annually. Although there will be shifts in population and types of industrial activity, the basic position of the economy of the area in relation to the Ohio Basin is not expected to change.

The Ohio River and minor tributaries, for purposes of discussion, can be conveniently divided into five reaches. They correspond approximately to the Upper Ohio, Ohio-Huntington, Ohio-Cincinnati, Ohio-Louisville and Lower Ohio-Evansville economic subareas. (See map, figure 0-1)

The Upper Ohio reach lies along 200 miles of the Ohio River from Pittsburgh to just below the mouth of the Hocking River and includes

portions of Pennsylvania, Ohio and West Virginia. The Allegheny, Monongahela, Beaver, Muskingum and Little Kanawha subbasins drain to the Ohio River within this reach. The once strong agricultural and mining economy has declined sharply since 1930. Manufacturing has become an important sector of the economy. Highest growth projections in industrial output for the area are in coal mining and the manufacture of machinery and electrical equipment. About 700,000 people live in the area. A modest increase in population is projected for 1980.

The Huntington reach from miles 200 to 400 spans the Ohio River from below the mouth of the Hocking River southward to below the mouth of the Scioto River, and focuses on the Huntington-Ashland metropolitan area. Runoff from the Kanawha, Guyandotte, Big Sandy-Little Sandy and Scioto subbasins empty into the Ohio River within this reach. Agriculture employment has declined while manufacturing employment has grown considerably since World War II. Primary metals and chemicals account for the largest shares of employment within the manufacturing sector of the economy. Output of the chemical industry is expected to triple by 1980. Over 530,000 persons live in the area. The population is expected to grow moderately through the 1970's.

The reach of the Ohio River dominated by the Cincinnati metropolitan area extends from Vanceburg, Kentucky, westward and southwestward to the Kentucky River. The Licking, Kentucky, Great Miami and Little Miami major tributaries empty to the Ohio River in this reach. In 1960, over one-third of the total employment in this area was in manufacturing with heaviest concentration in machinery and transportation equipment. Due to anticipated increases in manufacturing productivity, employment in this field is not likely to grow significantly beyond the 1960 level. However, considerable growth is projected in the services, finance and trade sectors. Over 1.3 million people populate this area, with 80 percent located in and near Cincinnati. The population is expected to increase by approximately 20 percent by 1980.

The Louisville reach of the Ohio River extends southwestward from the Kentucky River, mile 540 to Cannelton, Indiana. The Salt River is the only major tributary entering the Ohio River in this reach. The economy of the area is quite diversified. In terms of employment, machinery, lumber and furniture, tobacco, chemicals and food production are of considerable importance. Manufacturing accounts for 30 percent of total employment. Over 852,000 people live in this area, with 85 percent of them around Louisville. By 1980, total population is expected to increase by almost 35 percent.

The lower reach of the Ohio River centers on Evansville, a major population center and extends from Cannelton, Indiana, mile 720, to mile 981, the mouth of the Ohio River at Cairo, Illinois. The Green, Wabash

and Cumberland subbasins drain to the Ohio River in this reach. The Tennessee Basin also drains to the Ohio River in this reach but is excluded from the basin study area. The Saline River (minor tributary) entering from the northwest, drains 1,170 square miles and the Tradewater River (minor tributary) from the southern side of the Ohio River drains 1,000 square miles. Other minor tributaries are much smaller. From 1940 to 1960, labor engaged in agriculture declined from 26 to 10 percent of total employment, while manufacturing grew to 26 percent of total employment. Mining employment, contrary to the general trend in other subareas, is expected to increase due to the availability of coal resources for supplying an anticipated demand for electrical energy in the lower river. Of the more than 560,000 persons living in this area, 36 percent live in the Evansville area. An increase in population of 25 percent is projected by 1980, a growth rate slightly exceeding that of the Ohio River Basin.

2. Demand for Water and Related Functions and Services. - The concentration of economic activity along the banks of the Ohio River and adjacent areas has not only resulted in large demands for water, flood control, navigation, recreation, and other water oriented functions and services, but also has resulted in the aggravation of problems associated with municipal and industrial waste and other stream pollution. More intense use, additional development, and more efficient management of water and related land resources, along with diligent prosecution of other programs allied to water and land use, will be required to keep pace with projected demands for water and related functions and services along the Ohio River and in minor tributary areas.

Approximately 14 percent of the municipal and industrial water withdrawals in the Ohio Basin and over 45 percent of the water requirements for electric power cooling are taken from the Ohio River and minor tributaries. Twenty percent of the water withdrawals for agriculture and rural purposes within the Ohio Basin are withdrawn in Ohio River and minor tributary areas. Fulfillment of future demands for water will be contingent upon availability with acceptable quality at the time of need.

The maintenance of satisfactory water quality is a major concern along the entire Ohio River. Thermal pollution is a problem in some areas. In the minor tributaries, water quality problems exist at several communities. Although minimum natural flows on the Ohio River have been nearly doubled during low flow periods by release of stored water, increased waste loads continue to create pollution problems. Under conditions of treatment, existent in 1965, much of it only primary, pollution existed below the major cities at various times of low flow, especially during hot weather. Monitoring by the Ohio River Valley Sanitation Commission, ORSANCO, has shown that dissolved oxygen concentration below Pittsburgh, Huntington, Cincinnati and Louisville has been at times, less than 4.0 ppm, the minimum quality standard.

OHIO RIVER AND MINOR TRIBUTARIES

Flooding is still a serious problem on the Ohio River. A flood considerably greater than the flood of record could overtop existing levees and floodwalls and would cause catastrophic losses in life and property. Occurrence of such a flood is not very likely, but is a theoretical possibility. Additional storage capacity would reduce the risk of rare floods.

The coal mining industry together with the oil refining, chemical, steel producing and related industries are highly dependent on the availability of low-cost transportation for their products. The Ohio River, which carries 25 percent of the waterborne commerce within the United States, is the backbone of the Ohio River navigation system. Continual improvement of the waterway will be required to keep pace with growing demand.

Although facilities for fishing appear to be adequate through at least 1980, a deficiency in opportunities for outdoor recreation and hunting exists along the Ohio River and in minor tributary areas. This is particularly true for areas in and near the major metropolitan centers.

Minor tributary lands and agricultural areas along the Ohio River are in need of additional land treatment and management measures to control erosion, reduce sediment transport to streams and improve agricultural productivity.

a. Going Program Accomplishment. - Development and management programs instituted by Federal, state and local interests have generally solved the critical problems and provided for most urgent needs. Efforts have been underway for some time to solve pollution problems, reduce erosion, prevent flooding, improve water quality, improve the navigable waterway, and also provide for outdoor recreation, sport fishing, hunting, and other demands. Programs for land management and fish and wildlife preservation have been in effect for some time. Crop production methods are continually being improved; these, besides increasing land productivity, enhance conditions for retardation of runoff. The interest and cooperation between the states, communities and organizations who have a vital stake in development along the Ohio River has been a major asset in water resource planning.

Projects completed, under construction or in advanced planning as of July 1965 would prevent potential average annual damages of 88.7 million dollars along the Ohio River and 2.6 million dollars in the minor tributary areas. These potential damages along the Ohio River will be prevented by flood stage reduction afforded by 75 reservoirs located in the tributary subbasins in combination with 27 local protection projects along the Ohio River containing over 130 miles of levees, floodwalls and channel improvements. Reservoir capacity in the going program for regulation of flood flows on the Ohio River totals about 17 million acre-feet. Statistics as

to location, storage capacities, etc., of the individual reservoirs are covered in the subbasins where located.

Developments in the minor tributary areas consist of five reservoirs, five major and 15 small local protection projects, and 14 authorized upstream watershed projects. There are over 304,000 acre-feet of flood control storage and over 441 miles of levees, walls and channel improvements included in these projects.

The Ohio River is the principal source of water withdrawals for the municipalities and industries located along its banks. In areas where the water bearing alluvium is readily replenished by induced recharge from the Ohio River, yields from wells and ground water collectors are fairly large. About 20 percent of the water demand for municipal use is being obtained from ground water sources. This varies from a high of 58 percent in the upper Ohio reach to a minimum of 5 percent in the Cincinnati reach of the Ohio River. Sufficient water has generally been available to meet demand except during periods of extreme drought; but by 1980 steps must be taken to avert shortages, particularly in the tributary areas.

Much has been accomplished through the efforts of the Ohio River Valley Sanitation Commission (ORSANCO) toward restoring the "clear streams" status of the Ohio River and other streams from the standpoint of municipal and industrial pollution. ORSANCO reports that waste treatment facilities serve 99 percent of the 3.7 million people living in communities along the Ohio River. Construction of new treatment plants and improvements to existing plants continue. Over 80 percent of the industries along the Ohio River are meeting minimum waste treatment requirements. About 7 million acre-feet of storage capacity, for regulation of flows during low flow periods, was existent, under construction or in advanced planning in July 1965. Nearly all of this is provided in the major tributary subbasins draining to the Ohio River.

The entire length of the Ohio River is navigable for modern bargetows. The waterway is one of the most successful inland navigation routes in the world which in 1965 carried more than 100 million tons of freight in a movement exceeding 27 billion ton-miles. Under the current modernization plan, the river system will comprise 19 dam-lock units with slack water pools up to 114 miles long. Construction for the plan has been underway for more than a decade, and by 1965, 15 new navigation structures were in the going program providing an annual waterway capacity of 34 billion ton-miles.

There are many steam electric generating stations along the shores of the Ohio River. However, there are only 2 hydroelectric power plants in existence. The Markland navigation dam has an installation of 81 megawatts and McAlpine 80.3 megawatts. Both installations are privately owned. Provisions for future hydroelectric power facilities are included in the planning of the other navigation projects in the modernization program.

Recreation facilities provide opportunity for nearly three million visitor days along the Ohio River. It is estimated that over 80,000 pleasure craft use the river. In 1960, water related or enhanced outdoor recreational activity in the Ohio River and minor tributary area reached 11.6 million recreation days. In addition, sport fishing and hunting came to 2.5 million angler days and 3.1 million hunter days, respectively.

b. Future Demand. - See table O-1 for base year and projected increases in demand for water and related functions and services.

Water withdrawals are projected to increase from an average of about 10.5 billion gallons per day (1960) to 17.8 billion gallons per day by 2020. Withdrawals of 13.3 billion gallons per day to satisfy electric power cooling requirements account for 75 percent of the total. Withdrawals for municipal and industrial uses are projected to increase an additional 2.7 billion gallons per day to a total of 4.2 billion gallons per day by 2020. This is nearly triple the volume of water withdrawal in 1960. Water withdrawals for rural and farm use, as inventoried in 1960, were about 158 million gallons per day; by 2020 demand is projected to be about 300 mgd. Withdrawals for rural and farm use are a small fraction of total withdrawals.

Waste loads entering the Ohio River and minor tributaries are projected to increase in about the same proportion as the increase in water withdrawals for municipal and industrial use. By the year 2020, residual wastes discharged by municipalities and industries along the banks of the Ohio River and minor tributaries are projected to increase 2.7 times the 1960 average. Stream regulation during low flow periods will be required to insure that sufficient water is available to absorb these wastes without degrading water quality beyond acceptable limits.

Flooding will remain a serious problem on the Ohio River although the major tributary reservoirs and main stem local protection projects in the going program, when completed, would reduce potential average annual damages along the Ohio River from 100 million dollars to about 11.3 million dollars. Under conditions of flood plain development projected for 2020, potential average annual damages are estimated to reach 44.6 million dollars unless additional flood stage reduction is provided for the entire reach of the Ohio River, local protection projects at specific locations and more stringent flood plain management actions are undertaken for their prevention. The flood plains have great potential for industrial development. However, the benefit of locating in the flood plain must be carefully weighed against not only the possibility of physical damages and severe economic loss due to disruption of activities, but loss of life.

Residual annual damages in the minor tributary areas along the Ohio after completion of the going program for flood control, are estimated at 10.2 million dollars and are widely dispersed. Protective works and

management actions will be needed to mitigate potential average annual flood damages about double this amount with flood plain development projected for 2020.

Ohio River freight traffic is expected to grow over the period 1960-80 at an annual rate of 4 percent, reaching a total of 42 billion ton-miles in 1980. Early completion of the waterway modernization plan will be essential to accommodate this volume of traffic. Increased channel depths will be needed to physically accommodate the 117 billion ton-miles of riverborne commodities projected for the year 2020. The increased depth would provide for more efficient and economic use of the waterway and should be accomplished at an early date. The construction of potential new basin and interregional waterways could increase 2020 water transport demands on the Ohio River by another 10 billion ton-miles.

Additional electric power generation will be required to support industrial expansion and the general growth of the economy. Hydroelectric power plants could be efficiently utilized to provide about 10 percent of the total capacity requirements in the Ohio Basin.

Land area requiring treatment and proper management for efficient use is projected to increase to about 8.7 million acres by 2020. Some 66,000 acres of strip mined land are in need of rehabilitation, with 80 percent of the land located in the upper Ohio area and around Pittsburgh. By 2020, the irrigated land area is projected to increase from 5,600 acres as inventoried in 1960 to 127,500 acres, whereas land that may be economically drained may reach a total of slightly less than 2 million acres, an increase of 771,000 acres over that drained in 1960.

The demand for outdoor recreation is predicted to increase over 21 times the 1960 average use by 2020, an increase of 236 million recreation days. This demand, in conjunction with increased pressure for hunting and fishing opportunity, will require full use of water and lands affiliated with water resource development.

3. Resource Availability. - The average annual volume of flow in the Ohio River is generally sufficient in quantity to satisfy demands for water and serve other beneficial purposes; however, seasonal distribution is such that regulatory control of runoff is required to reduce flows during periods of excess and assure availability at times of need. A satisfactory quality of water can be maintained provided necessary pollution control measures are put into effect in combination with streamflow regulation to keep pace with the stream pollution problem.

The banks of the Ohio River provide for industrial developments, and transportation routes with low gradients and wide bends for railroads and highways. The waterway itself, of course, has been a main artery of

transport for a number of years. The highly developed flood plain and adjacent lands of the Ohio River Valley would make it uneconomical to build storage reservoirs on the Ohio River. Therefore, storage capacity for control of streamflow on the Ohio River must be located in strategically placed reservoirs in the various subbasins. The development potential of the minor tributaries appears to be adequate to provide the reservoir capacity required for streamflow control for most of the minor tributary area.

The hydroelectric power potential of the Ohio River and minor tributaries has not been fully investigated. The amount of Ohio Basin capacity requirements that can be satisfied along the Ohio River is unknown except for the conventional hydroelectric power in existence and identified as being potentially feasible at the Ohio River navigation dams. It may be feasible to develop pumped-storage facilities at several locations where the Ohio River is fairly well entrenched in relation to the general terrain adjacent to the river. Future detailed investigations will be required to determine the extent of this potential.

The scenic value of the Ohio River Valley should not be overlooked. Recreation areas can be built not only on the banks, but on the highlands overlooking the river. The minor tributary areas, which are generally forested, and some riverside land can be developed for game management. Both sport and commercial fishing can be further developed in the Ohio River and in the backwater pools formed on the tributaries by Ohio River navigation dams. Much of the 27.5 million pounds of commercial fish demand for the Ohio Basin could be satisfied from the Ohio River provided water quality control and fishery management programs are properly implemented.

The alluvial aquifers along the Ohio can and do provide water of relatively constant temperature and quality. The sand and gravel deposits in the valley hold abundant quantities of ground water. High rates of pumpage can be sustained because the aquifers are readily recharged by natural or induced infiltration from the Ohio River. The water is generally high in iron content and hard, but this has not prevented extensive development and use. Well yields are smaller in the lower reaches of the Ohio, but even here yields may be as high as 1,500 gpm. High yielding aquifers are not generally present in the small tributary drainages. Good aquifers are present, however, in sand and gravel deposits along the Hocking River in Ohio and in loosely consolidated sand and gravel south of the Ohio River, downstream from the mouth of the Tennessee River. Well depths generally vary from 30 to 150 feet.

4. Assessment of Resource Development Requirements. - Principal water supply, water quality and flood problem areas, together with reservoirs and upstream watershed projects in the going program of development, and those identified as potential future projects, are shown on the subarea map, figure O-1. Summary data for projects in the going program are given in

Appendix K, tables 15 through 21, and for identified potential projects in tables 24 through 28. The relationship of problem areas and projects in the going program is shown schematically in figure O-2, and key data relating to problem areas are given in table O-2. The schematic diagram was used for general orientation in analyzing problems and needs and establishing development requirements for streamflow control. An accounting of storage capacity for minor tributary streamflow control is given in table O-3. Results of the subbasin assessment to determine the magnitude and costs of resource development required to satisfy projected demands for water and related functions and services to serve the Ohio River and minor tributary subarea are summarized in table O-4. Ohio River flood control storage requirements are provided for in the major tributary subbasin analyses.

a. Requirements to be Furnished by Identified Resource Potential. Analysis of demands for water and related functions and services and of the means whereby these demands can be satisfied indicates that to solve water supply, water quality and flood problems, development of additional storage capacity for streamflow control will be required; also, further local protection projects and channel improvements will be required at several locations, either singly or in combination with streamflow regulation, to better cope with flood problems. The plan for control of streamflows assumes the following: available ground water will be utilized; organic wastes will receive adequate secondary treatment before release to streams; and appropriate flood plain management measures will be undertaken to minimize the need for storage reservoirs and other physical works for control of flood flows.

The major flow control problem on the Ohio River is associated with floods. Pittsburgh, Pennsylvania; Wheeling and New Martinsville, West Virginia; Marietta and Cincinnati, Ohio; and Evansville and Aurora, Indiana, are major urban flood damage centers. On the minor tributaries, Athens, Ohio, on the Hocking River, is a major urban damage center. Reservoir capacity required by 2020 to control Ohio River Standard Project Flood stages to the maximum of record is estimated to be approximately 26 million acre-feet in addition to the amount that will be available upon completion of the going program for flood control. Flood storage space to be provided in the major tributary identified projects for control of flood flows on the Ohio River totals about 15.3 million acre-feet, of which 11.4 million acre-feet is considered fully effective and required to aid in the control of the Ohio River Standard Project Flood. In addition to storage capacity located in the major tributary subbasins, 26 local protection projects with 58 miles of levees and floodwalls along the Ohio River have been identified. To control flood waters in the minor tributaries to the Ohio River, 1.6 million acre-feet of storage capacity are required. Five reservoirs with 175,000 acre-feet of capacity would provide control on both the Hocking River and on the Ohio River. Twenty-three other reservoirs, with 826,000 acre-feet of space disbursed throughout the minor tributaries, in coordination with eight major and two minor local protection projects would provide for

localized flood control. In addition, 493,000 acre-feet of a total storage potential of 2.3 million acre-feet in 117 potential upstream watershed projects would be utilized; flood channel improvements in upstream watershed areas total 1,254 miles.

Streamflow supplementation will be required at many localities to assimilate wastes discharged to streams from cities and industry. Thirteen localities are identified on the minor tributaries. Pittsburgh and Cincinnati serve as indices to Ohio River requirements. Fulfilling the projected flow requirements at Pittsburgh and Cincinnati will provide sufficient assimilative capacity to meet minimum dissolved oxygen standards at all intermediate and downstream points. As measured in 1965, 5,000 cfs were required at Pittsburgh. This will increase to 5,700 cfs by 1980 and 7,800 cfs by 2020. At Cincinnati, corresponding amounts are 8,000 cfs, 11,000 cfs and 13,200 cfs, respectively. Storage capacity available upon completion of subbasin reservoirs in the going program will generally provide sufficient flow for the assimilation of municipal and industrial wastes which have been treated to remove 85 percent of the biochemical oxygen demand until about 1980. To assimilate 2020 waste loads, additional flow will be required to prevent problems occurring during drought years. Storage capacity to be provided at identified sites in the various major subbasins will be sufficient to meet these requirements. Storage capacity required for water quality control on the minor tributaries is 235,800 acre-feet, of which 50,300 acre-feet can be provided in identified potential reservoirs.

Water withdrawal demands of municipalities and industries along the Ohio River can be satisfied during low flow periods by water made available by storage releases in the major subbasins for control of water quality and water supply. The ground water potential is considered adequate to provide an average of about 305 million gallons per day toward satisfying 2020 water requirements. About 1,677,000 acre-feet of reservoir capacity will be required in the minor tributary areas to satisfy water withdrawal demands. Potential capacity in identified reservoirs is 94,500 acre-feet.

Continual improvement of the existing waterway will be required to keep pace with demand for low cost transport of waterborne freight, and shortly after 1980 the navigable depth should be increased to 12 feet for the full length of the Ohio River.

An undeveloped hydroelectric power potential totaling 816 megawatts of installed capacity has been identified as being potentially feasible of development on the Ohio River. Conventional power installations would vary from 22 to 100 megawatts at 16 of the dams included in the navigation modernization program and would be in addition to the power plants at the McAlpine and Markland projects. The capacity would be useable prior to 1980 to meet a portion of the growing Ohio River Basin power requirements.

Inclusion of the power potential as an element of water resource development is based on judgment that the installations will prove to be desirable and economically feasible in comparison to alternative sources of power supply.

About 45 percent of the Ohio River and minor tributary area is included in potentially feasible upstream watershed projects and amounts to 5.8 million acres. Of this amount, it is estimated that approximately 3.2 million acres - predominantly in crop and pasture land - will require treatment and management by 2020 to enhance land productivity and serve other beneficial purposes. Retardation of runoff, control of erosion, and reduction of sediment transport to streams are important considerations.

Recreational opportunity equivalent to about 40.7 million recreation days can be provided by the Ohio River, and impoundments, reservoirs and other identified developments in the minor tributary areas if convenient access and adequate facilities are made available.

b. *Remaining Requirements*. - A total of 1,607,000 acre-feet of storage capacity in addition to amounts provided in the going program and identified potential reservoirs will be required in the minor tributary drainages to regulate flood flows and supplement streamflows during low flow periods. Storage for the control of water quality and to satisfy demands for water withdrawals totals 1,504,400 acre-feet. It includes an amount for water required in areas not identified by specific location of need and an amount required to provide streamflow regulation in several identified areas of need, but for which storage developments are not identified. Flood storage capacity of 103,800 acre-feet will be required on the Hocking River to assist in regulating the Ohio River Standard Project Flood flood stages to the maximum of record.

The extent to which demand for outdoor recreational opportunity can be satisfied beyond that provided by identified developments has not been assessed. It is apparent that the recreational potential of the Ohio River and developments in the tributary areas must be utilized to the maximum practical extent. It is likely that only a portion of the remaining requirements can be met in conjunction with other needed water resource development, particularly near the metropolitan population centers. The rest will have to be provided by other means. Local sport fishing demands can be satisfied and relieve pressure in other areas for several years into the future, but by 2020 further opportunity will be required. Improved fish and wildlife management on the Ohio River, and other streams and adjacent lands can do much to enhance fishing and hunting opportunity.

Remaining land treatment and management requirements are associated with the general land base outside watershed projects, with the exception that lands to be irrigated or drained may be located in or outside

watershed projects. By the year 2020, approximately 4.6 million acres of cropland, pasture, and woodland would be subject to treatment and management measures, some of the more common being contour farming of all types, controlled grassland farming, and improved forest management and utilization. These lands along with lands to be irrigated and others to be drained, are accounted for in the general inventory of requirements but are not identified by specific location.

TABLE O-1

OHIO RIVER, MINOR TRIBUTARIES
DEMAND FOR WATER AND RELATED FUNCTIONS AND SERVICES

	Unit	Base Year Amount	Projected Increase[1] 1980	2020
Water Withdrawal				
Municipal and Industrial[2]	Million Gallons Per Day	1,493.5	518.7	2,709.1
Electric Power Cooling	Million Gallons Per Day	8,820	1,320	4,470
Rural Communities	Million Gallons Per Day	127.1	24.5	73.0
Rural Domestic and Livestock	Million Gallons Per Day	26.94	0	12.42
Irrigation[3]	Million Gallons Per Day	3.7	6.9	57.3
Stream Assimilation of Organic Waste Effluent[4]	1,000 Population Equivalents	1,155.7	423.0	1,967.1
Flood Damage Prevention[5]	Million Dollars Annually	90.76	28.12	64.77
Waterway Freight Movement[6]	Million Ton-Miles Annually	34,000	8,000	93,000
Hydroelectric Power - Installed Capacity	Megawatts	161.3	(Assessed on a basin-wide basis)	
Outdoor Recreation	Million Recreation Days	11.6	82.4	236.0
Sport Fishing	Million Angler Days	2.51	0 [7]	1.03 [7]
Hunting	Million Hunter Days	3.10	0.63 [7]	1.02 [7]
Commercial Fishing			(Assessed on a basin-wide basis)	
Land Treatment and Management	1,000 Acres	822	2,789	7,863
Drainage	1,000 Acres	1,257	591	771
Irrigation (Land Area)	1,000 Acres	5.6	15.5	121.9

NOTES: (1) Base year amounts plus projected increase equals gross demands.

(2) Mining industry water requirements not included; assessed on a basin-wide basis.

(3) Withdrawal shown is for average year; drought year may be 45 percent higher.

(4) Residual biochemical oxygen demand after 85 percent waste removal by treatment.

(5) The dollar amounts (1980 and 2020) are indices to the magnitude of the problem and the protection measures required to reduce the potential damaging effects of floods.

(6) An index to the canalization and waterway facilities required to accommodate the transport of waterborne freight.

(7) Net requirements.

TABLE O-2

OHIO RIVER AND MINOR TRIBUTARIES
PRINCIPAL CONSIDERATIONS IN DETERMINING STORAGE CAPACITY REQUIREMENTS
FOR CONTROL OF STREAMFLOW

A. SUPPLEMENTAL STREAMFLOW REQUIRED AT KEY LOCATIONS TO CONTROL WATER QUALITY (CFS).

Problem Area(1)	Stream	Required Flow(2) 1980	Required Flow(2) 2020	Flow Provided by Going Program	Supplemental Flow Required 1980	Supplemental Flow Required 2020
Pittsburgh, Pa	Ohio River	5,700	7,800	5,600	100	2,200
McDonald, Pa	Robinson River	50	75	0	50	75
Washington, Pa	Chartiers Creek	50	75	2	48	73
Canonsburg, Pa	Chartiers Creek	10	22	0	11	22
Salem, Ohio	Little Beaver River, Middle Fork					
Lancaster, Ohio	Hocking River	35	55	25	10	30
Logan, Ohio	Hocking River	35	55	25	10	30
Athens, Ohio	Hocking River	35	55	25	10	30
Wellston, Ohio	Little Raccoon Creek	10	15	5	10	15
Cincinnati, Ohio	Ohio River	11,000	13,200	12,000	0	1,200
Batesville, Ind	Laughery Creek	15	25	5	10	20
Corydon, Ind	Big Indian Creek	15	28	0	15	28
Salem, Ind	Blue River	12	30	5	7	25
Harrisburg, Ill	Saline River	20	35	5	15	30

B. WATER REQUIRED TO SATISFY DEMANDS FOR WITHDRAWAL AND USE (IN ADDITION TO THAT PROVIDED IN BASE YEAR) (MGD).

Item	1980	2020
1. Total withdrawal(3)	1,870	7,322
2. To be provided by groundwater	63	305
3. Total consumptive use	87	406

C. FLOOD DAMAGE AREAS.

Location	Residual Damages(4) (Millions Dollars)	
1. Upstream areas	9.16	
2. Major urban areas(1)	3.52	
Steubenville, Ohio, Ohio River New Martinsville, W Va, Ohio River Marietta, Ohio, Ohio River Dayton, Ohio, Ohio River Aurora, Ind, Ohio River Evansville, Ind, Ohio River Wheeling, W Va, Ohio River Cincinnati, Ohio, Ohio River Pittsburgh Metropolitan Area, Pa, Ohio River Athens, Ohio, Hocking River Logan, Ohio, Hocking River		
3. Other flood plain areas	8.79	
4. Total subbasin	21.47	Projected to 28.12 in 1980 and 64.77 in 2020.

NOTES: (1) See figure O-1 for geographic location of principal problem areas and figure O-2 for schematic relationship.

(2) Streamflow required to maintain a minimum of 4 parts per million of dissolved oxygen.

(3) Water required to satisfy municipal and industrial, electric power cooling, rural community, rural domestic and livestock, and irrigation demands.

(4) Estimated average annual damages with the 1965 flood control program completed (1965 constant dollars).

TABLE O-3

OHIO RIVER, MINOR TRIBUTARIES
ACCOUNTING OF STORAGE CAPACITY FOR STREAMFLOW CONTROL
(IN ADDITION TO THAT PROVIDED IN THE GOING PROGRAM)

	Time Period	
	1980	2020
	Storage (1,000 Ac Ft)	
A. WATER QUALITY CONTROL.		
1. Storage required(1)	142.7	235.8
2. Storage provided in identified potential sites	36.3	50.3
3. Additional storage required	106.4	185.5
B. WATER WITHDRAWALS.		
1. Storage required	337.7	1,667.2
C. FLOOD CONTROL.		
1. Subbasin and Ohio River control requirement	326.5	1,597.4
2. Storage provided in identified potential sites	300.7	1,494.4
a. for solving localized problems	(181.1)	(493.2)
b. effective in controlling both subbasin and Ohio River flows	(119.6)	(1,001.2)
3. Additional storage required(2)	25.8	103.0
D. TOTAL STORAGE REQUIREMENT.		
1. Water quality control, water withdrawals, and flood control	806.9	3,510.4
2. Available in identified potential sites(3)	404.9	1,639.2
3. Joint use storage	60.1	263.8
4. Additional storage required(4)	341.9	1,607.4

NOTES: (1) Storage capacity required to provide supplemental flows at key urban locations and rural communities in upstream watershed areas.

(2) Remaining Minor Tributaries share of storage required to reduce the Ohio River Basin Standard Project Flood to the maximum flood stage of record.

(3) See figure O-1.

(4) Terrain indicates storage sites are potentially available.

TABLE O-4

OHIO RIVER, MINOR TRIBUTARIES
SUMMARY ASSESSMENT OF RESOURCE DEVELOPMENT REQUIREMENTS

Program Elements	Unit	Provided in Going Program	Additional Requirement[1] 1980 Amount	1980 Capital Cost ($1,000)	2020 (Accumulative) Amount	2020 (Accumulative) Capital Cost ($1,000)
PART 1. TO BE FURNISHED BY IDENTIFIED RESOURCE POTENTIAL WITHIN SUBBASIN.						
A. Streamflow Control and In-Stream Use						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	26.8	104.2	18,200	144.8	26,200
2. Control of Flood Flows						
a. reservoir and detention storage	1,000 Ac Ft	304.4	300.7	81,800	1,494.4	378,900
b. local protection projects	Miles	202.1	49.3	100,400	81.8	216,300
c. channel improvement	Miles	239	464	19,300	1,159	48,200
3. Navigable Waterway						
a. improvement to existing waterway	Miles of Channel	981	981	240,000	981	240,000
b. new waterway	Miles of Channel	-	-	-	-	-
c. channel deepening to 12 feet	Miles of Channel	-	0	0	981	50,000
4. Hydroelectric Power - Installed Capacity	Megawatts	161.3	816	91,800	(Assessed on a Basin-wide Basis)	
B. Related Programs						
1. Outdoor Recreation[2] [3]	Million Recreation Days	11.6	12.4	43,500	40.7	141,400
2. Watershed Project Land Treatment and Management[4]	1,000 Acres	822	1,213.9	30,300	3,219.7	80,500
COSTS - PART 1				625,300		1,181,500
PART 2. REMAINING REQUIREMENTS.						
A. Streamflow Control and In-Stream Use[5]						
1. Storage for Increasing Flows and Furnishing Water for Withdrawal and Use	1,000 Ac Ft	-	316.1	80,600	1,504.4	383,600
2. Storage for Control of Flood Flows	1,000 Ac Ft	-	25.8	6,600	103.0	26,300
3. Hydroelectric Power			(Assessed on a Basin-wide Basis)			
B. Related Programs						
1. Outdoor Recreation[2] [6]	Million Recreation Days	-	70.0	244,400	195.2	684,800
2. Fish and Wildlife						
a. sport fishing[2] [6]	Million Angler Days	2.51	0	0	1.03	3,600
b. hunting[2] [6]	Million Hunter Days	3.10	0.63	2,200	1.02	3,600
c. commercial fishery			(Assessed on a Basin-wide Basis)			
C. Land Treatment and Management						
1. Lands Outside Watershed Projects	1,000 Acres	-	1,574.6	39,400	4,643.3	116,100
2. Irrigation (Acres to be Irrigated)	1,000 Acres	5.6	13.7	1,300	111.7	10,300
3. Drainage	1,000 Acres	1,257	529.8	74,200	686.8	96,100
COSTS - PART 2				448,700		1,324,400
TOTAL COSTS - (PARTS 1 AND 2)				1,074,000		2,505,900

NOTES:

(1) Requirement in addition to that provided by going development programs.

(2) Costs shown are for initial facilities and such measures as may be required to implement the program and do not include water and related land cost. Base year 1960.

(3) The number of outdoor recreation days shown include some sport fishing and hunting which could not be separately accounted for in available data.

(4) Land area and costs shown are for total land treatment and management requirements in watershed projects and cover both water resource development related and other lands.

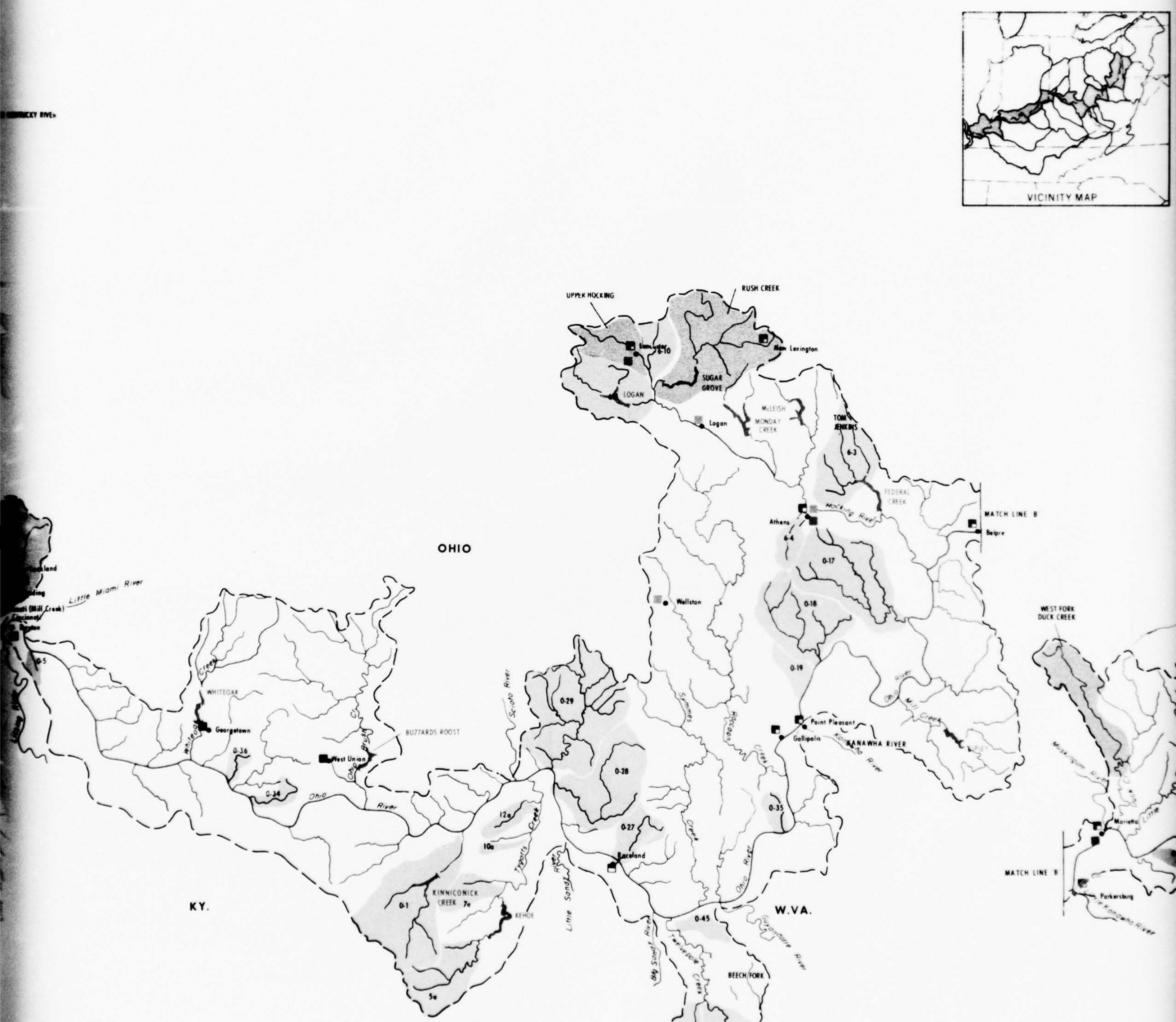
(5) Specific sites to provide storage capacity for streamflow control are not identified; however, favorable storage sites are potentially available.

(6) Because of population and resource distributions, remaining subbasin requirements for outdoor recreation, sport fishing and hunting not satisfied by water resource developments may require a trade off with adjacent subbasins or satisfied by other means.

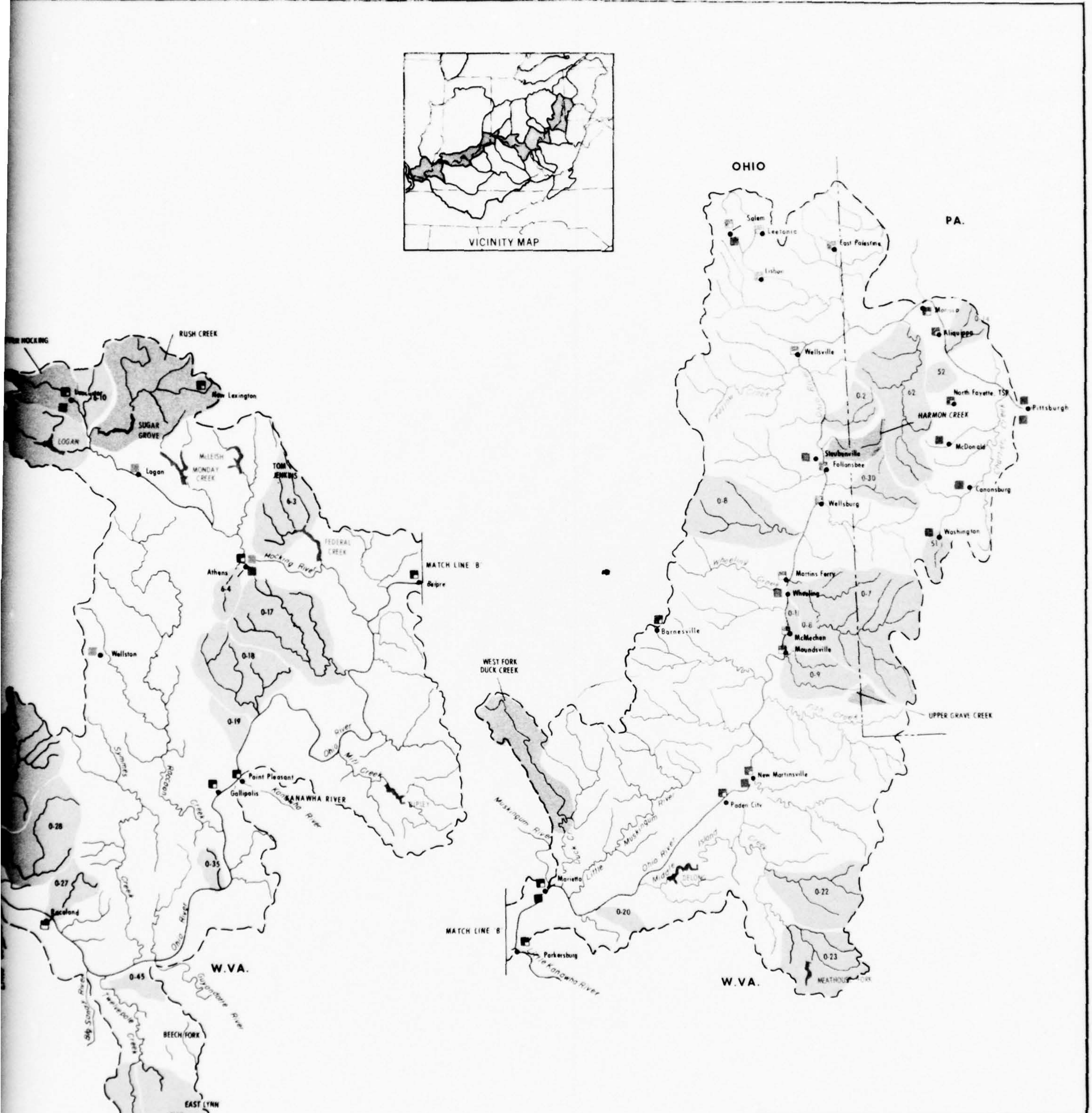
Mcleansboro
18-14
BEAR CREEK
18-13
Eldorado
18-10
18-8
BUSHY CREEK
Harrisburg
STONEFORT
LITTLE CACHE
00-14
00-17
00-21
00-16
00-19
18-3
18-2
00-25
0-36
0-35
0-34
0-37
00-13
0-38
0-40
HUMPHREY CLANTON
Saline River
Ohio River
Wabash River
Cumberland River
Tennessee River
0-33
CYPRESS CREEK
0-30
CANOE CREEK
CRAB ORCHARD CREEK
Providence
19-8
19-9
19-3
19-2
DONALDSON CREEK
UPPER TRADEWATER
07-2
07-4
Evansville
Green River
07-5
07-7
07-8d
07-8e
07-8f
Boonville
Little Pigeon
LH-1c
LH-1d
LH-1e
LH-1g
LH-10
LH-11
LH-12
LH-9
LH-7
LH-3
LH-5
Owensboro
0-28
0-26
0-25
IND
KY.
MIDDLE FORK ANDERSON RIVER
Anderson River
LH-14
LH-15
LH-17
LH-21
LH-22
LH-23
Tell City
Ohio River

MATCH LINE A
Salem
07-9
07-15
07-10
Charlestown
LITTLE KENTUCKY RIVER
MIDDLE FORK ANDERSON RIVER
LH-22
LH-23
LH-30
Jeffersonville
Corydon
LH-14
LH-21
LH-31
Ohio River
Silver Creek
Anderson River
LH-15
LH-17
LH-32
LH-35
Tell City
Ohio River
Salt River
0-26
0-25
IND.
0-43
Batesville
Great Miami River
WEST FORK
Lockland
Reading
Cincinnati (Mill Creek)
Cincinnati
Dayton
Little Miami River
OHIO
Greendale
Lawrenceburg
Aurora
0-7
0-5
Rising Sun
0-8
Licking River
WHITEOAK
Whiteoak Creek
Georgetown
0-36
BUZZARDS ROOST
West Union
Scioto River
Madison
0-12
Ohio River
0-34
12a
10a
MATCH LINE A
Kentucky River
KINNICONICK CREEK
7a
KEHOE
0-1
5a
KY.
LEGEND
1. PROJECTS IN GOING PROGRAM
Corps of Engineers Reservoir
Watershed Project
Significant Non-Federal Reservoir
2. POTENTIAL PROJECTS
Reservoir
Watershed Project
3. PROBLEM AREAS
EXISTING
1980
2000
Water Quality
Water Supply
Major Flood Damage
10 0 10 20 30
SCALE IN MILES

2


VICINITY MAP
OHIO
KY.
W.VA.
UPPER HOCKING
RUSH CREEK
New Lexington
LOGAN
SUGAR GROVE
Logan
McLEISH
MONDAY CREEK
TOM JENKINS
6-3
FEDERAL CREEK
Athens
6-4
Hocking River
MATCH LINE B
Belpre
0-17
0-18
0-19
Wellston
WEST FORK DUCK CREEK
Little Miami River
0-5
Creek
WHITEOAK
Georgetown
Whiteoak
0-36
West Union
BUZZARDS ROOST
Scioto River
0-29
0-28
0-27
Symmes Creek
Raccoon Creek
Point Pleasant
Gallipolis
KANAWHA RIVER
Kanawha River
Ohio River
Mill Creek
0-34
Ohio River
12a
10a
Tygarts Creek
Raceland
0-35
Muskingum River
Marietta
MATCH LINE B
Parkersburg
Little Kanawha River
KINNICONICK CREEK
0-1
7a
KEHOE
Little Sandy River
0-45
Big Sandy River
Twelvepole Creek
Guyandotte River
BEECH FORK
5a
EAST LYNN
0-47
1980
2000
10 0 10 20 30 40
SCALE IN MILES

3



OHIO RIVER BASIN COMPREHENSIVE SURVEY

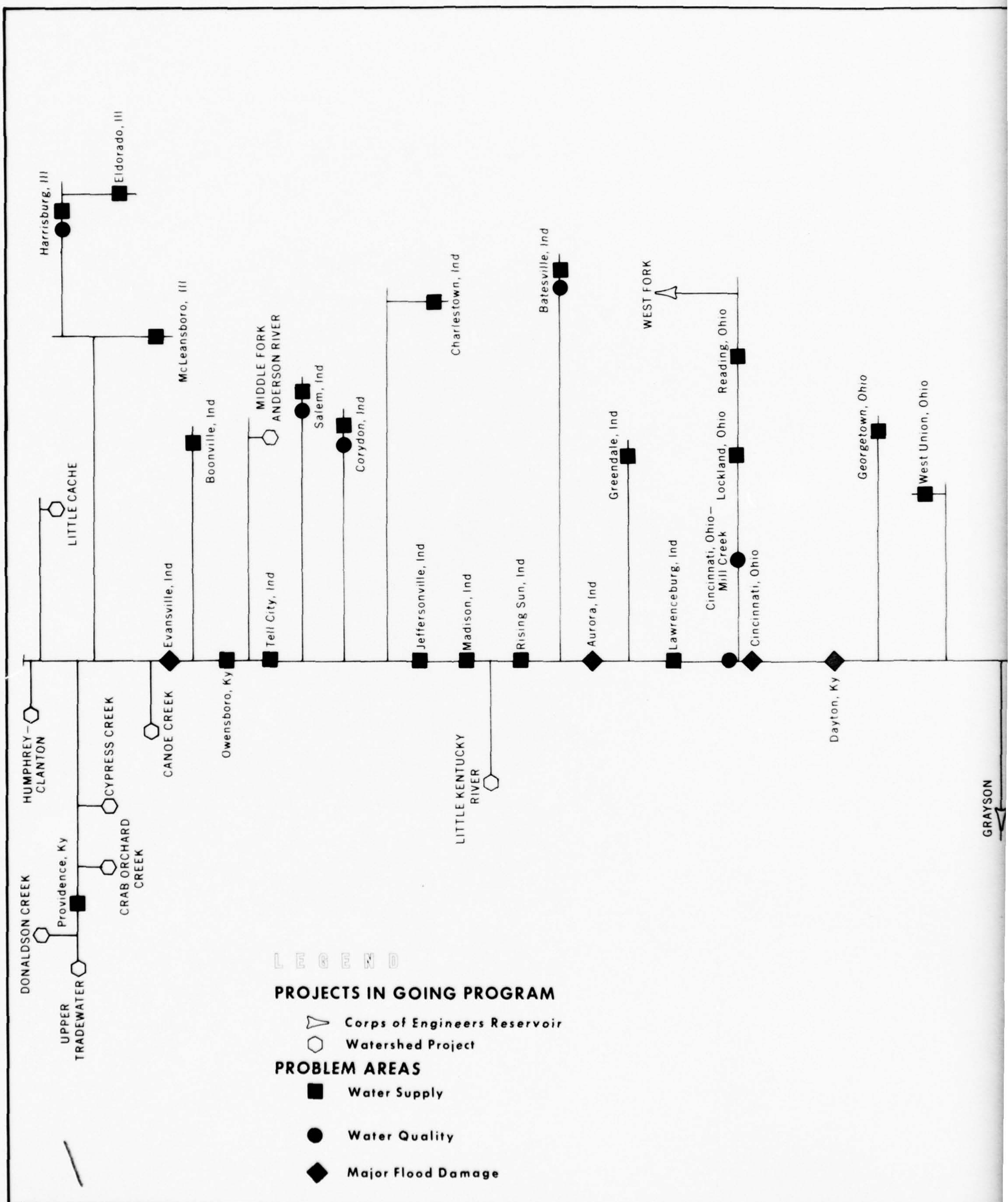
OHIO RIVER AND MINOR TRIBUTARIES

PRINCIPAL
WA ER SUPPLY, WATER QUALITY AND FLOOD
PROBLEMS

RESERVOIRS AND WATERSHED PROJECTS
IN GOING PROGRAM, AND POTENTIALS

CORPS OF ENGINEERS
APPENDIX K

U.S. ARMY OHIO RIVER DIVISION
FIGURE 0-1



DONALDSON CREEK
UPPER TRADEWATER
Providence, Ky
CRAB ORCHARD CREEK
CYPRESS CREEK
HUMPHREY–CLANTON
LITTLE CACHE
Harrisburg, Ill
Eldorado, Ill
McLeansboro, Ill
CANOE CREEK
Evansville, Ind
Boonville, Ind
Owensboro, Ky
MIDDLE FORK ANDERSON RIVER
Tell City, Ind
Salem, Ind
Corydon, Ind
Charlestown, Ind
Jeffersonville, Ind
Madison, Ind
LITTLE KENTUCKY RIVER
Rising Sun, Ind
Batesville, Ind
Aurora, Ind
Greendale, Ind
Lawrenceburg, Ind
WEST FORK
Reading, Ohio
Lockland, Ohio
Cincinnati, Ohio–Mill Creek
Cincinnati, Ohio
Dayton, Ky
Georgetown, Ohio
West Union, Ohio
GRAYSON
LEGEND
PROJECTS IN GOING PROGRAM
Corps of Engineers Reservoir
Watershed Project
PROBLEM AREAS
Water Supply
Water Quality
Major Flood Damage

M
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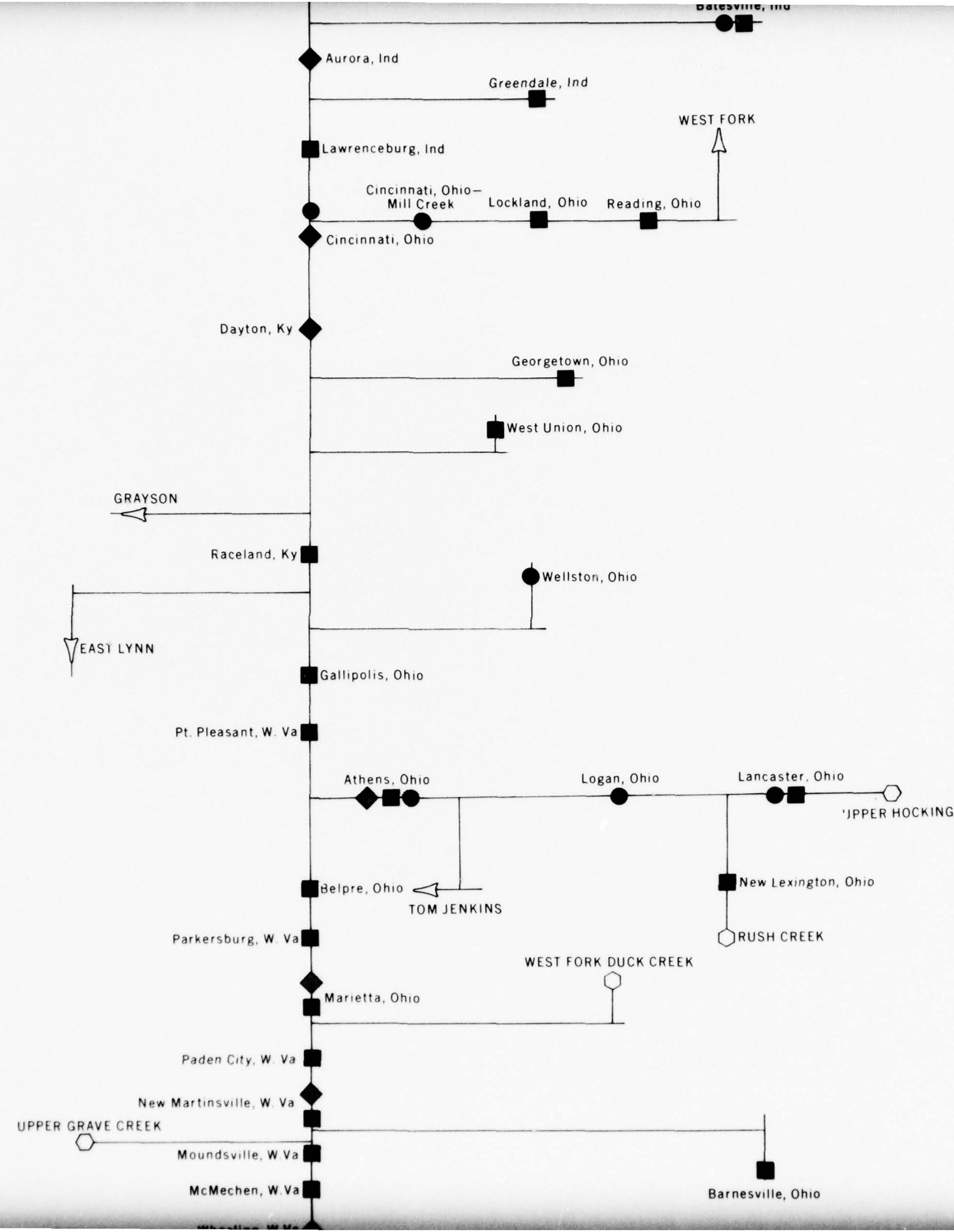
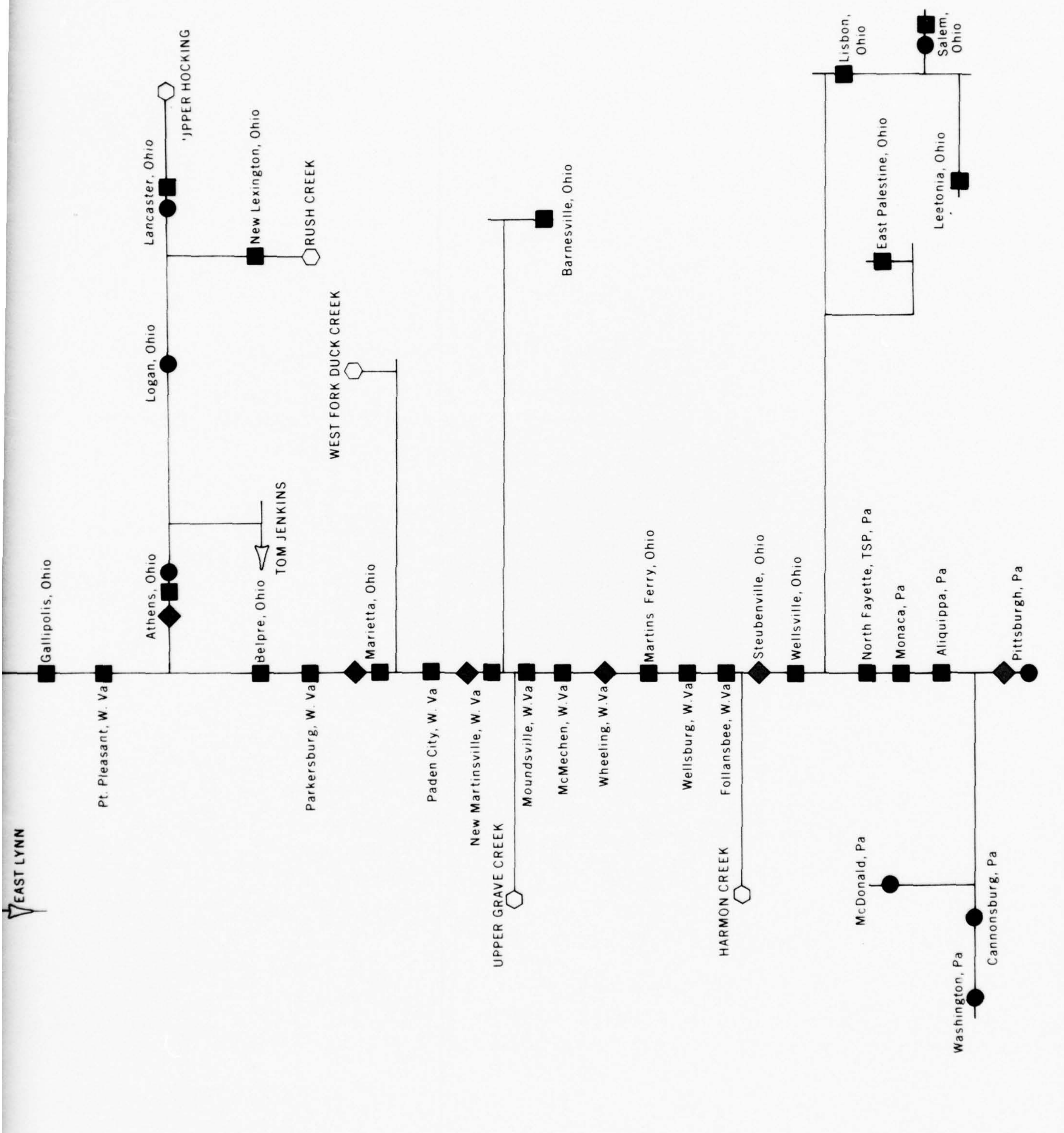


Batesville, Ind
Aurora, Ind
Greendale, Ind
WEST FORK
Lawrenceburg, Ind
Cincinnati, Ohio—
Mill Creek
Lockland, Ohio
Reading, Ohio
Cincinnati, Ohio
Dayton, Ky
Georgetown, Ohio
West Union, Ohio
GRAYSON
Raceland, Ky
Wellston, Ohio
EAST LYNN
Gallipolis, Ohio
Pt. Pleasant, W. Va
Athens, Ohio
Logan, Ohio
Lancaster, Ohio
'JPPER HOCKING
Belpre, Ohio
TOM JENKINS
New Lexington, Ohio
Parkersburg, W. Va
RUSH CREEK
WEST FORK DUCK CREEK
Marietta, Ohio
Paden City, W. Va
New Martinsville, W. Va
UPPER GRAVE CREEK
Moundsville, W. Va
McMechen, W. Va
Barnesville, Ohio

2



OHIO RIVER BASIN COMPREHENSIVE SURVEY

OHIO RIVER AND MINOR TRIBUTARIES ANALYSIS SCHEMATIC

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION

APPENDIX K FIGURE O-2

APPENDIX K

ATTACHMENT B

MINERAL RESOURCES AND MINING

APPENDIX K

ATTACHMENT B

MINERAL RESOURCES AND MINING

TABLE OF CONTENTS

ATTACHMENT B

MINERAL RESOURCES AND MINING

SECTION I. INTRODUCTION

Mineral resources and mining have had a major impact on the settlement and economic development of the Ohio River Basin. Consequently, they have played an important role in the development of water resources and will be a major influential factor in future water and related land resource developments. They are most significant to the basin economy, water supply needs, streamflow quality, land reclamation needs, water and transportation, thermal power and reservoir sites. This portion of the appendix is a brief summary of the mineral resources and mining and their relationship to water resource development in the Ohio River Basin. The mineral resources are intimately related to geology. General bedrock and unconsolidated sediments are delineated on plates 3 and 4 of Appendix E, Ground Water.

SECTION II. MINERAL PRODUCTION AND ECONOMIC VALUE

Total United States mineral production in 1964 was $20.472 billion, the Ohio River Basin's portion being approximately 12 percent.

Coal is by far the leading mineral product; it comprised about 8 percent of the value of United States mineral production and about 68 percent of the value of the Ohio River Basin mineral production in 1964.

In addition to coal, the basin percentage of U.S. production of various commodities in 1964 was: fluorspar, 27; clay, 16.3; stone, 11.4; cement, 10.4; sand and gravel, 7.9; gypsum, 7; zinc, 6; natural gas liquids, 5; salt, 4.2; lime, 3.8; petroleum, 3; natural gas, 2.4; and lead, 2.3. Some peat, gem stones, abrasive stones, iron ore (pigments), barite and silver also were mined.

Table B-1, prepared by Area I, Mineral Resources Office, Bureau of Mines, shows the 1964 production of selected mineral commodities. Both tonnage and value are recorded and, in most cases, subarea as well as total basin production are reported.

Actual and estimated values of the basin 1964 mineral production follows:

Coal	$1,682,846,852*
Clay	28,272,946*
Stone	130,962,018*
Sand and Gravel	78,218,000*
Cement	120,647,530
Salt	11,946,590*
Lime	7,744,672
Fluorspar	8,145,000
Gypsum	2,742,250
Petroleum	258,829,000
Natural Gas	97,481,000
Natural Gas Liquids	44,023,000
Lead	1,750,000
Zinc	9,015,000
Miscellaneous	1,130,000
Total	$2,483,753,858

*Actual values furnished by U.S. Bureau of Mines

TABLE B-1

PRODUCTION OF SELECTED MINERAL COMMODITIES - 1964

Economic Subarea	Sand and Gravel Short Tons	Sand and Gravel Value	Stone Short Tons	Stone Value	Clay Short Tons	Clay Value	Coal Short Tons	Coal Value
A Allegheny	2,869,000	$ 4,139,000	1,052,779	$ 2,049,054	763,725	$ 5,091,142	27,758,090	$ 126,642,053
B Monongahela	173,000	472,000	2,774,134	4,795,026	(1)	(1)	51,068,864	253,867,861
C Pittsburgh SMSA	(1)	(1)	748,821	1,349,469	(1)	(1)	22,867,346	133,890,604
D Beaver	(1)	(1)	(1)	(1)	642,788	1,346,280	4,043,781	14,439,750
E Upper Ohio	4,540,000	5,971,000	258,267	503,143	806,556	6,115,471	19,134,828	75,807,684
F Muskingum	6,349,000	9,263,000	2,808,702	6,363,792	2,463,660	6,035,567	20,595,077	75,613,826
G Kanawha-Little Kanawha	204,000	271,000	5,401,597	8,310,107	85,462	170,111	45,618,256	216,910,445
H Ohio-Huntington	1,528,000	2,360,000	1,168,556	3,677,878	441,785	2,050,247	2,496,009	8,080,840
I Scioto	6,961,000	7,311,000	5,377,222	7,503,026	302,792	582,631	78,602	260,122
J Guyandotte-Big Sandy-Little Sandy	(1)	(1)	(1)	(1)	52,460	348,811	94,555,565	452,645,244
K Ohio-Cincinnati	5,911,000	7,444,000	1,098,332	1,540,591	-	-	-	-
L Little Miami-Great Miami	11,514,000	12,339,000	3,598,563	4,664,951	(1)	(1)	-	-
M Licking-Kentucky-Salt	-	-	6,922,422	10,154,110	(1)	(1)	15,339,596	56,821,089
N Ohio-Louisville	3,461,000	3,215,000	7,568,967	9,596,284	639,900	801,012	-	-
O Lower Ohio-Evansville	2,328,000	2,355,000	6,392,784	7,575,541	236,888	526,184	15,703,421	56,271,772
P Green	(1)	(1)	3,968,517	5,598,542	-	-	32,652,244	106,179,899
Q White	8,663,000	7,669,000	10,242,641	24,421,196	936,761	1,286,004	5,833,097	22,705,728
R Wabash	9,794,000	8,633,000	6,045,703	8,562,321	348,574	624,448	10,195,086	35,703,356
S Cumberland	1,011,000	1,620,000	10,061,284	12,727,605	(1)	(1)	10,952,387	47,006,579
Undistributed	3,306,000	5,156,000	6,920,018	11,569,382	878,013	3,295,036	-	-
TOTAL	68,612,000	$78,218,000	82,409,309	$130,962,018	8,599,364	$28,272,946	378,892,249	$1,682,846,852

NOTE: (1) Breakdown on distribution of these items not available.

TABLE B-2

MINERAL PRODUCTION - 1960, 1964, AND PROJECTED

		1960	1964	1970	1980	1990	2000	2010	2020
GNP	Billions of $ 1954 Prices	439.9	500.9	626.0	874.3	1,202.8	1,677.2	2,271.2	3,142.4
Coal	Millions of Short Tons	316.7	379	459	795	1,042	1,397	1,843	2,764
	Millions of $ 1960 Prices	1,485	1,778	2,153	3,729	4,887	6,552	8,644	12,963
Clay	Millions of Short Tons	8.0	8.6	9.8	12.3	15.6	20.4	26.3	35.0
	Millions of $ 1960 Prices	26	28	32	41	52	68	87	116
Stone	Millions of Short Tons	70.3	82.4	111.1	166.7	241.7	349.8	485.3	684.1
	Millions of $ 1960 Prices	108	127	170	257	372	539	747	1,054
Cement	Thousands of 376 Lb. Barrels	33,384	36,231	47,083	68,659	97,238	138,511	190,189	266,983
	Millions of $ 1960 Prices	113	123	160	233	330	470	645	905
Sand and Gravel	Millions of Short Tons	56.1	68.6	95.3	144.3	209.0	302.7	419.4	585.4
	Millions of $ 1960 Prices	57	69	96	146	211	306	424	591
Salt	Millions of Short Tons	1.1	1.3	1.5	2.5	3.6	5.3	7.3	10.2
	Millions of $ 1960 Prices	7	8	10	16	23	34	47	66
Lime	Millions of Short Tons	.4	.6	.8	1.2	1.8	2.6	3.6	5.1
	Millions of $ 1960 Prices	5	8	11	16	24	35	48	68
Petroleum	Thousands of Barrels	88,755	85,863	81,533	74,303	67,073	59,843	52,613	45,383
	Millions of $ 1960 Prices	255	247	235	214	193	172	152	131
Natural Gas	Millions of Cubic Feet	388,240	376,088	357,860	327,480	297,100	266,720	236,340	205,960
	Millions of $ 1960 Prices	54	53	50	46	42	37	33	29
Natural Gas Liquids	Millions of Gallons	760	902	1,115	1,115	1,015	893	795	700
	Millions of $ 1960 Prices	43	51	64	64	59	51	45	40
Other Minerals	Millions of $ 1960 Prices	20	23	28	44	58	77	102	150
Total Basin Mineral Value	Millions of $ 1960 Prices	2,172	2,515	3,019	4,806	6,251	8,341	10,974	16,113

SECTION III. PROSPECTS AND PROBLEMS

Prospects appear good for the basin to continue as a significant mineral production area for the next 60 years. Vast reserves of most mineral commodities exist and many have been explored and studied. In a number of areas the mineral rights to large blocks of reserves have been obtained by producers, and use patterns by industry have been established. National economic growth will increase mineral production throughout the country, with a resultant benefit to the basin.

Projections of future basin mineral production are given in table B-2. The projections are based on 1964 production, the basin percentages of the U.S. total for 1960 and the projected total for the nation. Although this will not be exactly the case, it is believed that the basin is typical of the nation insofar as mineral production is concerned and that the basin's percentages of National production will remain relatively constant. The exceptions are petroleum and natural gas which showed a marked decline over a 25-year period. This same rate of decline was projected to 2020. Consequently, for these two minerals an estimate was made of the percent of each state's production which came from the basin. The average yearly rate of decrease in production between 1940 and 1964 for each state was assumed to continue to 2020 in making projections. Average 1960 U.S. prices were used to obtain dollar values.

In 1964, in addition to the commodities shown in table B-1, other mineral production amounted to approximately .94 percent of the total mineral value. In order to obtain a projected value for other minerals it was assumed that they would account for .94 percent of the total during the period of projection.

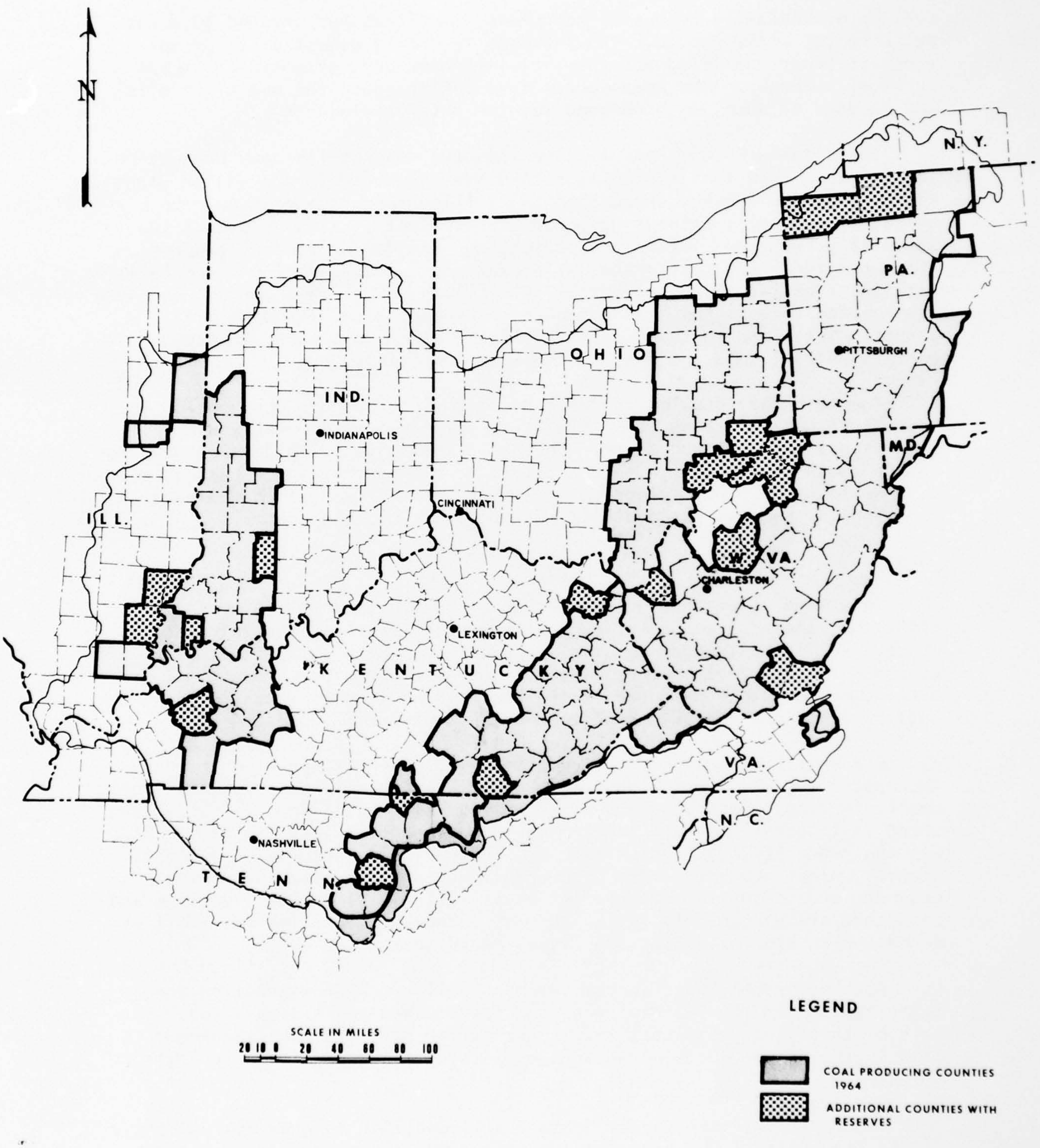
Table B-2 cannot accurately predict basin mineral production for the 60-year period. It does, however, give an indication of the magnitude of growth.

The following paragraphs briefly cover the prospects and problems by commodities.

Coal

In establishing high standards of living and assuring continuity of industrial progress, energy has played a leading role. Of all the fossil-fuel sources, coal is the most abundant. The U.S. has one-third of the world coal reserves. Nearly 80 percent of U.S. coal is bituminous and sub-bituminous. In 1964, the basin produced 77.7 percent of the U.S. total of coal. All coal produced in the basin was bituminous coal and semi-anthracite. Figure B-1 shows the counties which produced in 1964 and those having reserves, but no 1964 production.

Coal is extracted from the earth by underground, auger, and strip mining. Modern mechanization has achieved high productivity, great safety, and a minimum of manual labor. After being mined, about 65 percent of the



OHIO RIVER BASIN COMPREHENSIVE SURVEY

COAL RESOURCES

CORPS OF ENGINEERS U.S. ARMY OHIO RIVER DIVISION
APPENDIX K FIGURE B-1

coal is mechanically processed to remove impurities and crushed to sizes suitable for ultimate use. The coal may be burned domestically or to generate power, gasified for industrial or home use, or coked for metallurgical purposes. The by-products from coking (gas, tar and light oils) can be used as such, or processed for the chemical industry.

The bituminous coal and lignite industry reached its peak production in 1947 when more than 630 million tons were produced in the United States. In 1961, production had dropped to 403 million tons, due primarily to competition of oil, natural gas, and nuclear fuels. As a result of the steadily growing population and increasing demands for thermal generation of power, there has been a steady increase in coal production since 1961, with the 1965 figure approximating 507 million tons. This gradual increase is expected to continue. As a result of technological research, it is expected that important new uses for coal will be developed, including conversion to liquid and gaseous fuels at competitive cost.

The principal problem in relation to coal output and consumption is the development of means to enable it to compete more favorably with oil, natural gas and nuclear energy. The basic challenge is to develop ways to reduce costs of production, preparation, and transportation. Methods must also be found to provide increasing efficiency and greater convenience in use, and in the disposal and utilization of its waste products.

Stone

This term refers not only to crushed and broken stone, a basic construction, chemical and metallurgical raw material, but also to dimension stone used for buildings, memorials and other structures. Limestone accounts for about 71 percent of total U.S. crushed stone production. Most dimension stone produced in the basin is sedimentary rock. The Indiana limestone and Ohio sandstone are well-known examples.

Presently, dimension stone competes at a disadvantage with an ever-increasing variety of other building materials, largely because it is more costly to mine, prepare, transport, and install. Additionally, the modern trend is to construct buildings having a much shorter life expentancy than was customary 50 years ago. There is, however, a renewed recognition of stone's unique properties for ornamentation and for protection against the weather, and demand for many varieties is rising. Dimension limestone and sandstone are used mainly for buildings, although quantities are still produced for curbing, flagging and miscellaneous uses.

Accelerated highway, industrial and public works construction are major factors in the increasing demand for crushed and broken stone. The bulk of this production goes into construction projects; the remainder is used in cement manufacture and for chemical, metallurgical and agricultural purposes.

It is predicted that the industry will continue to grow approximately at the same rate as the national population and economy. Its growth

closely parallels trends in such basic economic indicators as gross national product, value of construction, and population. Reserves close to market areas are being depleted at a high rate, but adequate sources of supply remain at progressively greater distances from consumption centers.

The competitive position of crushed stone in relation to sand and gravel, slag and lightweight aggregates makes cost control a major operating requisite. Quality control is also an important factor; rigid requirements have produced many different specifications for crushed stone for various purposes. Zoning regulations continue to be a serious factor because they handicap the utilization of deposits close to metropolitan areas and require the development of more distant deposits. Other perennial problems relate to improving mining and processing techniques (i.e., research on blasting practices to reduce damage from vibration), transportation and exploration methods and equipment.

Sand and Gravel

U.S. production of sand and gravel has increased 250 percent during the past 20 years, the volume exceeding that of any other mineral commodity. At the point of production, more than 97 percent is valued at less than $2 per ton. Cost of transportation to distant markets may amount to much more than value at the mine, and markets are generally confined to within a few miles of the deposits.

Sand and gravel for concrete and bituminous aggregate accounts for 96 percent of total production. The glass industry is one of the most important users. Sand and gravel also is used to make molds for castings in iron and steel foundries. Smaller amounts are utilized for ceramics, stone sawing, sand blasting, glass grinding, stone polishing, fillers in paints, plasters, and cements, abrasive materials in soaps and polishing compounds, and as filter sands in municipal water plants. The chemical industry uses silica sand in the manufacture of sodium silicate, silica gels, calcium silicate and in a wide variety of silicones.

Some of the problems of sand and gravel production, such as low unit value and high transportation costs are universal. Others, such as seasonality of operation, influence of day-to-day weather changes, stockpiling and reclamation, disposal of waste water and undersized material, changes in specifications and market areas, and restrictive zoning legislation, may be more localized.

Clay

Clay minerals are hydrous aluminum silicates; a variety of types are found in nature. The principal industrial clays are kaolin, ball, fire, bentonite and fuller's earth. About 57 percent of the clay produced is used in manufacturing brick and ceramic and refractory products, 34 percent in producing cement and lightweight aggregates. The remainder is used for fillers and numerous miscellaneous applications.

In the basin, the principal production is fire clay, used for refractories, heavy construction products and stoneware. Miscellaneous clay is used for brick, cement, lightweight aggregate, refractories, and stoneware.

Production of clay and shale for lightweight aggregates will continue to increase at a rate somewhat slower than in the past. In some local areas, the high-grade fire clay deposits apparently are becoming exhausted. Competition from other refractories is increasing because of technological changes, and because of higher maintenance and replacement costs of the fire clay refractories. Output of clays and shales for brick, tile and other such construction products should maintain the present level or perhaps increase somewhat.

Geologically, fire clays underlie many coal seams. Because of the anticipated increase in strip mining in the basin, many important clay deposits will be exposed, and with proper planning could be recovered. This may counteract somewhat the reduction in available reserves due to exhaustion of known high-grade deposits and might result in lower clay production costs. These factors, together with continued research will, it is expected, permit the basin to continue producing the present percentage of total National clay production.

Cement

Concrete is the most widely used manufactured construction material in the world. Almost twice as much concrete is used in the U.S. as all other mineral structural materials combined.

Basin reserves of raw materials for Portland cement, including fuels required for cement production are adequate for many years. Quarries now providing material to some plants may be exhausted, but additional reserves of limestone and shale are available to replace them.

New production machinery and methods have constantly lowered cement production costs. At the same time, more rigorous specifications for cement and more varied consumer tastes and needs have proliferated special types on the market. New automated bulk transportation equipment and local market distribution centers permit the industry more flexibility in meeting customer needs.

Continued growth of the cement industry is forecast as population increases generate a need for more highways, schools, dams, housing and industrial plants. Some recent stimulants to the cement industry are the introduction of prestressed concrete, soil-cement paving, thin-shell cantilevered concrete roofs, sculptured and exposed-aggregate panels, lightweight concrete, expansive cement, precasting, slip-form casting and factory-built modular units. Continued technological innovations will hold the cost of concrete at favorable levels in relation with competitive building materials.

Salt

Sodium and chlorine, supplied primarily by salt, are essential to modern man. Sodium compounds are used in the preparation, processing or production of many things he eats, drinks, touches and sees.

Nationally, salt is produced by conventional and solution mining, recovering natural brines, and evaporation of saline lake and sea water. In the basin, practically all salt is produced by solution mining, pumping fresh water into underlying rock salt beds and recovering the artificial brine. Salt reserves are vast and pose no supply problems.

The chemical industry is the largest consumer of salt, using two-thirds of the U.S. output. Quantities are also used for road stabilization, highway snow and ice removal, regeneration of water softeners and domestic use.

Problems of the industry are chiefly those of maintaining or lowering production and marketing costs so that salt may continue as a high-volume, low-unit-cost commodity. Other problems relate to the corrosive nature of salt solution on plant equipment and on vehicles and roads when it is used for snow and ice removal. The salt may be flushed into the watercourses causing pollution problems.

Lime

The production of lime and magnesium lime in the basin is from limestone and dolomite (calcium magnesium carbonate). Calcination of these materials at moderately high temperatures releases carbon dioxide gas and leaves behind a solid residue of quicklime or calcined dolomite. Addition of water to quicklime causes rapid hydration to calcium hydroxide, or hydrated lime.

Quicklime and hydrated lime is required in larger quantities to satisfy the growing needs of modern civilization. To the few original uses in building and agriculture have been added thousands of chemical and industrial uses. Most quicklime and hydrated lime enters into chemical and industrial applications. Smaller quantities are employed in construction in mortar and plaster, used in construction in soil stabilization, and in agriculture as a soil neutralizer and conditioner.

Many problems are encountered in quarrying, calcining, hydrating, storing, handling and transporting. At some operations collecting and utilizing pulverized limestone waste, using by-product carbon dioxide and recovering or disposing of lime sludge are problems. Attention is being directed toward the improvement of kiln design and determining the fundamental nature and properties of lime itself.

Petroleum and Natural Gas

The petroleum and natural gas industry has experienced phenomenal growth in recent years and now supplies three-fourths of all our fuel

energy needs. The U.S. has only about 10 percent of present worldwide reserves, however, and the industry therefore has been working diligently to improve its economy. Research efforts are under study on technical problems covering the entire range of oil and gas activities. Improvement of production methods is a major study area. On the average, only 30 to 35 percent of the oil discovered is recovered before the economic limit is reached. Likewise, numerous petroleum resources are submarginal economically and cannot be produced with present technology. Among the innovations for oil recovery are several secondary recovery methods to supplement water flooding.

Drilling and producing costs have been increasing due largely to the fact that the average depth of producing wells is becoming greater. Individual segments of drilling costs have increased only slightly; but as wells go deeper, their cost is greater. The industry is confronted with larger exploration expenditures which have contributed to the upward trend in the cost of finding domestic crude oil. But the major reason for increased unit exploration costs is that most of the new discoveries are small oil and gas accumulations and consequently the industry is paying more to discover less.

Oil production in the basin declined 18 percent and gas production 17 percent in the 25 years from 1940 to 1964. This decline occurred while demand for oil and gas was increasing at a rate of about six percent each year. Demand was met by importing both oil and gas into the basin, primarily by pipeline and barges.

Natural Gas Liquids

Some underground gas reservoirs contain hydrocarbons which condense as pressure is released, forming natural gas liquids. From such reservoirs, these extractable constituents range in amount from 10 to 75 barrels per million cubic feet of gas.

In recent years in the United States and in the Ohio River Basin, use of such liquids has been increasing and 1964 basin production was valued at approximately 44 million dollars. As production of oil and gas in the basin continues to decline, it is expected that use of natural gas liquids will first reach a maximum and then its production will decline with decline of natural gas production. Production of natural gas liquids in both Illinois and Pennsylvania already had declined between 1960 and 1964. In the projection for the basin, the 1960-64 rate of increase was extended to 1970; the 1970 rate of production was anticipated from 1970 to 1980; and beyond 1980, it is believed production will decrease at about the same rate as natural gas production.

Other Minerals

Fluorspar, or fluorite, is produced in Hardin and Pope Counties, Illinois, and Livingston and Crittenden Counties, Kentucky, all in the Lower Ohio-Evansville Basin subarea. Most of the United States production of fluorspar comes from this area and most of the domestic reserves are here.

Fluorspar is used in the steel, glass and enamel industries, and for the manufacture of aerosols, refrigerants, plastics and hydrogen fluoride. United States consumption far exceeds production and more than half the fluorspar is imported. Since there are presently no adequate substitutes for fluorspar to manufacture fluorine, the outlook is that the consumption in the basin should increase at the present rate or more rapidly. One of the industry problems is the need to pump large quantities of water from the mines, thus adding substantially to production costs.

Gypsum is mined in Martin County, Indiana, in the White Basin subarea. Plaster made from gypsum is one of the oldest building materials and its use continues to grow. Consumption is closely related to fluctuations in the building construction field. As population grows, requirements for buildings will grow and the need for gypsum will increase. Large deposits of gypsum occur in various parts of the U.S., but basin production is expected to keep pace with the economy and production of other mineral commodities.

Moderate amounts of lead and zinc are produced in Wythe County, Virginia, and additional deposits may be found in some surrounding counties. A little lead, zinc and silver are also produced in connection with fluorspar mining in Kentucky and Illinois.

Some barite was produced in 1964 in Crittenden County, Kentucky, and some iron ore pigment in Pulaski County, Virginia.

Indiana, Illinois, Ohio and Pennsylvania all produced peat in 1964.

Minor amounts of abrasive stone and some gem stones were also found.

SECTION IV. WATER NEEDS RELATED TO MINING AND THE MINERAL INDUSTRY

The mineral industries of the Ohio River Basin used over 300 billion gallons of water in 1962. Presently, 64 percent of the bituminous coal produced in the United States is washed and processed before delivery. Some 86 percent of the sand and gravel produced is processed. Large quantities of water are used in the petroleum and natural gas industries for well drilling, for secondary recovery operations and for natural gas processing. In the salt industry, fresh water is pumped into the rock salt formations and the brines produced are recovered. The crushed stone industry requires water in its processing procedures. Minor amounts of water are used in the lime, cement and clay industries.

Detailed information, however, on water use by various segments of the mineral industry, particularly on a basin-wide basis, is difficult to obtain. The following tabulations provide summary information on water use:

Water Use Per Ton of Crude Material Handled
(Selected Commodities, U.S. Totals), 1962 (1)

	Gallons of Water Per Ton of Crude Material				
Commodity	New	Recirculated	Total	Discharge	Consumed
Bituminous Coal	102	445	547	84	18
Salt	3,617	1,101	4,718	2,752	865
Sand and Gravel	325	183	508	308	17
Stone	83	26	109	77	6

Water Use in the Ohio River Basin, 1962 (1)
(Millions of Gallons)

	Mineral* Industry	Petroleum and Natural Gas, Well Drilling, Secondary Recovery and Natural Gas Processing	Total
New Water Input	66,110	23,018	89,128
Recirculated Water	161,627	50,182	211,809
Total Water Usage	227,737	73,200	300,937
Water Discharge	58,251	13,951	72,202
New Water Consumed	7,859	9,436	17,295

*Chiefly bituminous coal, salt, sand, gravel and stone.

In considering future water needs, it must be kept in mind that not only will larger quantities of various mineral commodities be produced, but also that a greater percent of those produced will require processing. As the economy grows and more minerals are required, it will be necessary to use lower-grade ores which require more processing to get a ton of usable material. At the same time, users will be requiring higher quality products.

By 1985, it is anticipated that 75 percent of the coal produced and 95 percent of the sand and gravel produced will be processed. Crushed stone probably will require more total water as specifications are improved, while salt, cement, clay and lime will use about the same amount per ton produced. As petroleum and natural gas production declines in the basin, less water may be used for gas processing, but more may be required for the secondary recovery of oil, thus indicating a usage in 1980 similar to that of the present.

The following tabulation is a summary of projected mineral industry water use based on the assumption that most of the water will continue to be used by the coal, salt, sand and gravel, stone and petroleum and natural gas industries. Utilizing presently available data, this summary was prepared to indicate the order of magnitude of water use by the mineral industry:

Mineral Industry Water Use in the Ohio River Basin
(Millions of Gallons)

	1962	1980	2000	2020
New Water	89,128	186,367	355,631	691,180
Discharged Water	72,202	157,750	307,590	602,547
Consumed Water	17,295	28,986	48,410	89,002

SECTION V. WATER PROBLEMS CREATED BY MINING

As mining activity increases in the basin, the quantity of water consumed will increase. Furthermore, the water not consumed but used by the industry and then discharged can cause problems.

Presently 65 percent of the bituminous coal production of the nation is processed. This requires an average of 102 gallons of new water for each ton processed. Of this quantity, 18 gallons are consumed and 84 discharged. Coal impurities such as rock, ash-forming material and sulphur-bearing components are carried by the discharge and are potential causes of pollution unless the water is treated before discharge. By 1985, when coal production in the basin may be three times the 1960 amount, it is estimated that some 75 percent of the production will be processed, indicating a considerable increase in the quantities of water from coal processing plants which will need treatment.

At present, the most serious water problem created by mining in the basin is acid mine water. This water drains primarily from abandoned coal mines, although some active coal and clay mines also may produce it. This problem is discussed in connection with water quality control needs in this appendix and in greater detail in Appendix D.

In 1962, some 86 percent of the United States sand and gravel production was processed. Of the 325 gallons of new water required per ton, 17 gallons were consumed and 308 discharged. The discharge from sand and gravel processing carries varying amounts of fine material, depending on the composition of the deposit being worked, and these finer materials can cause serious siltation problems unless removed in settling ponds before discharge of water. In 1985, when sand and gravel production may be three times the 1962 rate, it is expected that 95 percent will be processed.

Similar problems exist in the crushed stone industry where 83 gallons of new water, 6 of which are consumed and 77 discharged, are required for each ton produced. Here again it is the finer material which generates the difficulty.

In the salt industry, 3,617 gallons of new water are required for each ton of production. Of this, 865 gallons are consumed and 2,752 discharged. Serious stream pollution can and has occurred, if the process water is not properly treated before release.

In the drilling of oil and gas wells, salt brines often are encountered. These and other oil field wastes cause serious water pollution problems if not properly contained.

SECTION VI. RELATIONSHIP OF MINING TO OTHER WATER AND LAND RESOURCE ACTIVITIES

Surface mining of coal, clay, sand, gravel and stone relates closely to water problems. This method of mining coal involves many acres of the surface of the basin. Presently, more than 30 percent of the U.S. bituminous coal production is produced by this method, and in Ohio, it is used to mine 70 percent of the coal.

Changes in rate of streamflow, rate of erosion and siltation and in acidity can all be regulated by proper watershed management. A virtual wasteland can be produced through mismanagement. This problem is discussed at some length in Appendix F.

Surface subsidence due to underground mining is a problem which can have an affect on water and related land resource planning. Many abandoned underground mines, particularly those close to the surface, have carried surface subsidence. In some coal mining plans, after regular mining has been completed the supporting pillars are systematically removed, increasing the amount of coal recovered but sometimes causing surface cracking and settling. Similarly, some surface areas where underlying salt has been solution mined are reported to have subsided. The possibility of such surface weakness should be thoroughly investigated where dams, locks and other water control structures are contemplated in mining areas.

Damage due to noise, vibration, and dust, and the presence of heavy trucking are problems of the stone, sand and gravel, lime and cement industries. Many times, as a result of one or more of these, restrictive zoning forces these industries to move farther from their markets, thus increasing production and delivery costs.

Long-range planning and proper zoning which would permit and encourage the removal of minerals, and the reclamation of the land before urbanization, might aid in the solution of some of these industry problems.

Another facet of the mining problem concerns cost of transportation. Because of the low unit value of the products, many cement, sand and gravel, stone, and coal producers locate on water transportation routes. This is particularly true if the markets are located on such arteries.

Some transportation cost problems are being reduced by the use of the unit-train, which is the shipping of an entire trainload of a product from one producer to one customer. Research is also under way on integral trains. These will be long trains of larger cars for which special types of loading and unloading facilities will be used. These transportation innovations should be considered in comprehensive water planning, since the location of dams and reservoirs often affects railroads involved in mineral transportation. Longer hauling routes may be feasible in the future.

Another form of transportation which is of vital economic importance is the vast network of oil and gas pipelines. Since the basin now produces

only a small portion of the oil and gas it consumes, these pipelines are lifelines of the economy of many areas. Their locations affect economic growth. Pipelines may conflict with potential water resource development sites necessitating high relocation costs.

APPENDIX K

ATTACHMENT C

HISTORICAL AND ARCHEOLOGICAL THEMES

APPENDIX K

ATTACHMENT C

HISTORICAL AND ARCHEOLOGICAL THEMES

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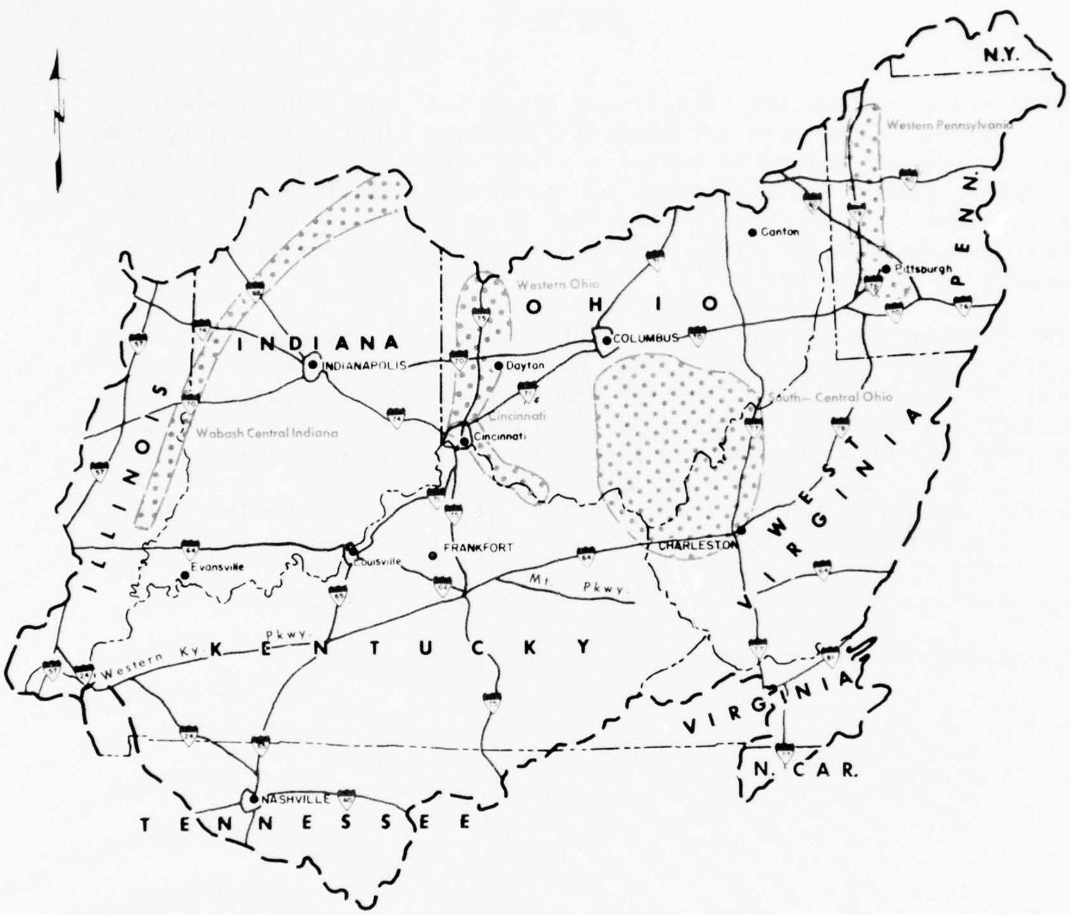
PREFACE

This study reviews the significant historical and archeological themes relevant to the area encompassing the Ohio River drainage system. It does not present a list of historic sites nor is it a general history of the area. Rather it is a survey of nationally significant historic themes in terms of specific, related land and water areas which, the National Park Service believes, should be explored in greater detail and perpetuated in some manner.

The Prehistoric Period, from roughly 15000 B.C., is dealt with basin-wide. Most of the sites of the Historic Era are grouped into four main geographic areas: Western Pennsylvania, South-Central Ohio (which includes portions of Kentucky and West Virginia), Western Ohio, and Central Indiana (the Wabash drainage area). See figure C-1. The study of each of these areas examined ten historic themes: Early Exploration and Settlements, the Advance of the Frontier, Early Political Affairs, Transportation, Social Movements, Industry, Science and Invention, Education, the Civil War, and Political Affairs (1865-1912). No main geographic area contains examples of all ten themes.

Local history is not considered in this study.

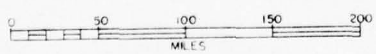


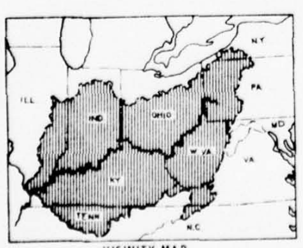
LEGEND

● MAJOR CITIES

INTERSTATE ROUTES

CENTERS OF SIGNIFICANT HISTORICAL THEMES





VICINITY MAP

OHIO RIVER BASIN COMPREHENSIVE SURVEY

CENTERS OF SIGNIFICANT HISTORICAL THEMES

NATIONAL PARK SERVICE | U. S. DEPT. OF THE INTERIOR

APPENDIX K | FIGURE C-1

SUMMARY

Rivers have always played a major role in history; the Ohio is no exception. It has a significant story to tell, a story that is an integral part of our nation's heritage.

The story begins with the archaic successors of the Paleo-Indians and the moundbuilders that followed them. So far as these people are concerned, the entire Ohio Basin, but especially the Scioto River drainage in the State of Ohio, can be termed the archeological part of prehistoric America. No significant stream in that State is without archeological sites, often of the first magnitude of importance. The most spectacular are the Hopewellian geometrical earthworks and funeral mounds (600 B.C. to 600 A.D.). Next are the earthworks of the proto-historic Fort Ancient culture, directly preceding the historic Shawnee and related tribes. These significant sites should be carefully conserved.

Historic Indians and early Europeans both used the Ohio River as their major transportation artery. Its strategic importance led to the French and Indian War and gained the river for the English. In 1783 the Ohio River Basin became part of the United States. When the Northwest Territory - the territory northwest of the Ohio - was opened to settlement in 1787, the Ohio was the route for the flood of settlers who poured into the new lands of mid-America.

Commercial transportation on the Ohio River was seriously impeded in the 19th century - by lack of canalization and by the completion of the great canal building era of the early 1800's, together with the extensive railroad construction that followed - but today commercial traffic is steadily rising. The colorful era of the steamboat was born on the Ohio River and had its heyday here in the mid-19th century.

Progress has changed the Ohio River's appearance. It will never again appear as it did to La Salle when he first saw it in 1669. But every effort should be made to retail those vestiges of our heritage which this great waterway helped create.

THE PREHISTORIC PERIOD IN THE OHIO RIVER DRAINAGE

(15000 B.C. - 1700 A.D.)

After the last glacial advance withdrew northward from central North America, the cool, moist climate provided lush grass and forests that in turn supported large animals such as the mammoth, giant bison, musk ox, mastodon and the giant ground sloth. In search of these game animals came hunting bands of aborigines known as the "Paleo-Indians."

When the Paleo-Indians first arrived in the Ohio Valley is not yet established. But by 8,000 years ago they roamed this great drainage system leaving campsites with ephemeral evidence other than their remarkably well made flaked chert and calcedony spears and knives and the occasional remains of a kill. With the exception of a skull of a girl found in Brown's Valley, Minnesota, the identity of these hunting peoples is known only by reference to the classification and occurrence of these artifacts. No burials of the Paleo-Indians have been discovered in the Ohio River Basin.

With the development of the "Altithermal" climate of today, i.e., the period of high temperatures, relative to the preceding cool era, the inhabitants of the Ohio River Basin came to depend upon the fauna that characterized the environment - deer, game birds and many small game animals. The Paleo-Indians began to depend on seeds, fruit, tubers and roots to supplement their meat diet.

During the "Archaic Cultural Era" that followed the big game hunters, between 7000 and 5000 B.C., the Indian camps became semi-permanent. The warmer temperatures and the reduced water flow over the riffles or shoal areas of the Tennessee, Green and Kanawha Rivers was an ideal habitat for freshwater clams and mussels. Along these tributaries, shellfish became an increasingly important food source.

For the next 4,000 years, most of the Indians of this drainage system followed a seasonal round of activities, having several established campsites and spending part of the year in each, depending on what local food supply was in season. At some shellfish campsites, by living on their garbage dumps, the Indians accumulated as much as 42 feet of debris. This was a local condition, however; most sites had no appreciable depth.

About 1000 B.C. a wide diversity of regional cultures came into existence, brought about by increased population, dependence upon local resources and an improved technology. At least one group, the Adena of southern Ohio and central Kentucky, began the cultivation of sunflowers and cucurbits. The most important development of this period was the appearance, shortly after 1 A.D., of maize among the Hopewell.

During this period a new burial practice was introduced - the construction of mounds over the graves. It reached its culmination, in a religious fluorescence we call Hopewell, about 300 B.C. with major centers in the Scioto drainage and southern Illinois and spread rapidly through most of the area north of the Ohio River. The practice gradually disappeared, spreading south of the Green River about 300 A.D., and lasting longest, perhaps, in eastern Tennessee and the upper Ohio area.

Sometime prior to 1000 A.D. a totally new way of life developed, characterized by improved maize agriculture, large towns, pyramidal temple mounds, wattle and daub house construction and new techniques of pottery manufacture. The bow and arrow preceded this development in some drainages by a couple of hundred years, but cannot be considered part of it.

In the southwestern portions of the Ohio drainage system, this major development may have been accompanied by an influx of emigrants. There is good reason to associate these developments with Meso-America; the morphological similarities between the areas are great. The actual process by which the Meso-American got here has not been worked out.

In the more eastern portions of the drainage system, the new development was brought about by the introduction of new ideas. As this development moved up the Ohio and its side drainages, it was absorbed into the existing ways of life. By the time it reached the Monongahela it had little effect on the Indian way of life, other than in maize agriculture. Large villages were rare above the Kanawha River; temple mounds and wattle and daub house construction were rare above the Falls of the Ohio (present-day Louisville, Kentucky).

Historic tribes in the Ohio River drainage system include the Cherokee in the upper Tennessee drainage, the Creek in the middle Tennessee drainage, the Chickasaw in the lower Tennessee drainage, the Illinois north of the lower Ohio River, and the Shawnee in the central Ohio River drainage. In the late 17th century the Miami moved in west of the Shawnee.

Important Prehistoric Indian Sites

5000 B.C. - 1000 B.C. Two important sites of this period are Indian Knoll (Green River) and St. Albans (Kanawha River). Both are on private lands, are undeveloped, but have been extensively excavated.

1000 B.C. - 1000 A.D. Major sites of this period include Mound City, Hopewell and Hopeton (Scioto River); Fort Ancient, Fort Hill and Serpent Mound (Little Miami River); Newark (Muskingum River); Grave Creek (upper Ohio River); and Adena Park (Kentucky River).

Mound City Group is a National Monument preserved by the National Park Service. Fort Ancient, Fort Hill, Serpent Mound and a part of Newark are Ohio State Memorials. Part of Newark is a city park. Grave Creek is a West Virginia State Park. Adena Park is preserved by the University of Kentucky. Only Hopewell and Hopeton are on private land and are undeveloped. Only three of these sites have not been extensively excavated: Hopeton, Fort Hill and Newark.

1000 A.D. - 1700 A.D. The most notable sites of the southwestern portion still preserved are Angel and Kincaid, both on the lower Ohio River, and Wycliff at the mouth of the Ohio River.

Angel Site is an Indiana State Memorial, and has been extensively excavated. Kincaid Site is owned by the Metropolis City National Bank of Metropolis, Illinois, and has been extensively excavated. Wycliff State is owned by the Baptist Hospital of Paducah, Kentucky, and has been extensively excavated.

Prominent sites of the more eastern portions are Buffalo (Kanawha River), Madisonville (Little Miami River) and Fox Farm (central Ohio River). All are on private lands, remain undeveloped but have been extensively excavated.

Historic Tribes. Important sites of this period are Logstown (upper Ohio River), Lower Shawneetown (mouth of the Scioto River) and Eskipipitheki (Kentucky River). None of these sites has been preserved; a portion of Lower Shawneetown has been excavated by the University of Kentucky.

THE WESTERN PENNSYLVANIA GEOGRAPHIC AREA

This area centers on the Allegheny, Monongahela and upper Ohio Rivers. There are no significant prehistoric Indian sites, even though the area was heavily populated in prehistoric times. The site of Logstown, an important Indian village of historic tribes, was located on the Ohio, just north of Pittsburgh.

Early Explorers and Settlements. Early English explorers and traders from Virginia and Pennsylvania came into the Ohio Basin through the Monongahela Valley and down the Ohio River. Land companies, such as the Ohio Company and the Loyal Company, were formed and granted large tracts in the Ohio Valley by colonial assemblies. With this added incentive, the British colonists pressed even more.

The French, who had earlier entered the basin, but favored the Maumee-Wabash River routes, saw the increase of English traders as a real threat to their interests in the lower Ohio and the Missouri. By mid-eighteenth century, they had established a series of forts in western Pennsylvania, at Erie, Waterford and Franklin. The pressing of the English resulted in the French and Indian War, ending with a decisive English victory in 1763, and opening the region to English colonists.

The Commonwealth of Pennsylvania has established an historic site at Waterford (Fort Le Boeuf); the City of Pittsburgh is in the process of restoring Fort Pitt. Military aspects of the French and Indian War are adequately covered at Fort Necessity National Battlefield Site, a unit of the National Park System.

Transportation. By 1833, the Cumberland (or National) Road had been completed through this area and on to Wheeling, West Virginia. A toll house, near Uniontown, Pennsylvania, is a site of exceptional value along this road.

Social Movements. The most significant of America's social and humanitarian movements in the Ohio River drainage area were the utopian communities of the first half of the 19th century. An outstanding example of these communities is preserved at Old Economy Village, Ambridge, Pennsylvania. No further study is recommended.

Industry. In 1760, a coal mine was opened opposite Fort Pitt. Fifty years later, the stretch of river from Pittsburgh to Wheeling, West Virginia, was well set in the industrial pattern it follows today.

Early oil industry got its start in the Ohio drainage and is preserved through the Drake Well Memorial Park, Titusville, Pennsylvania, and Pithole City, Plumer, Pennsylvania.

THE SOUTH-CENTRAL OHIO GEOGRAPHIC AREA

This area includes the middle Ohio River, the Scioto, the Kanawha, the Little Kanawha, the Hocking and the Muskingum Rivers and includes south-central Ohio and portions of West Virginia and Kentucky. It is perhaps the most significant geographic area relating to history within the Basin.

Significant Indian sites, previously described, include St. Albans (Kanawha River), Mound City, Hopewell and Hopeton (Scioto River), and Newark (Muskingum River).

Early Explorers and Settlements. Very few English colonists settled west of the Alleghenies before 1763. The story of early explorers in the Ohio drainage is covered under the Western Pennsylvania area and the central Indiana area.

Advance of the Frontier. Lord Dunmore's War, a significant phase of early Indian relationships with the white settlers, has had little interpretation and should be studied within this geographic location. This area should also be investigated for the many important Indian trails, Tecumseh's birthplace, and the Indian campaign which culminated in the Battle of Point Pleasant.

The development of the Northwest Territory is complex and should be the basis for further study. Historical sites relating to this theme have been preserved at Marietta, Ohio, (land office building of the Ohio Land Company), and at several other locations within the drainage. The story is not fully told, however, and some significant sights, such as the headquarters of Governor St. Clair, in Chillicothe, Ohio, (Basin Subarea I - Scioto), are in constant danger of destruction. Further thought should also be given to Blennerhassett Island, where Aaron Burr planned his expedition to set up a new nation in the southwest.

Transportation. The early transportation theme as it applies to south-central Ohio requires further study. Although this theme is certainly much in evidence throughout the drainage area, it is felt that special reference should be made to it with regard to this specific geographic area.

In 1795 the Wilderness Road was opened to wagon traffic and facilitated settlement of the lower Ohio Valley. The next year Congress authorized construction of Zane's Trace, the first road running through Ohio, connecting Wheeling, West Virginia, and Maysville, Kentucky. After 1803, a portion of the money obtained from the sale of public lands in Ohio was set aside for road construction. By 1818 the Cumberland Road was completed to Wheeling, and by 1833 it reached Columbus, Ohio. Along these early turnpikes flowed an immense wagon traffic, featuring the Conestoga Wagon, which rivaled river commerce.

By 1830 the turnpike boom began to fade and the success of the Erie Canal stimulated the states in the old northeast into the canal business. Ohio built two trunk canals, one of which passed through south-central Ohio connecting Cleveland and Portsmouth.

The famous S-bridge of the Cumberland Road at New Concord, Ohio, is a site of exceptional value. The Zane Trace has several markers, but its path should be further defined and preserved. Traces of the Ohio and Erie Canal, built in 1833, remain today and should be defined and marked.

Industry. For over a quarter-century, the center of the iron industry was Hanging Rock on the Ohio River, downstream from Pittsburgh (Basin Subarea H). The boom began in the 1830's and lasted through the Civil War. But the new ore and coalfields gave out and the 18,000 square-mile Hanging Rock field was dead. The center for iron making moved back upstream to Pittsburgh.

In 1843 along the Kanawha River near the Great Salt Lick the largest flow of natural gas discovered to that date was struck.

Pottery manufacture was first established in the Ohio Valley at East Liverpool, Ohio. Good clay and skillful management resulted in enormous production. An early center was at Zanesville.

Buckeye Furnace Park, west of Clarion, Ohio, contains remains of some of the early Hanging Rock iron furnaces; the region definitely should be explored further.

Education. Manassah Cutler Hall, completed in 1819, on the campus of Ohio University in Athens, is the oldest college building in the Northwest Territory. Alexander Wade's system of graduation in country schools was adopted nationally. Wade lived in Morgantown, West Virginia.

THE WESTERN OHIO GEOGRAPHIC AREA

This area centers on Cincinnati, the middle Ohio, the Miami and the Little Miami Rivers, and includes part of Kentucky.

Significant Indian sites, previously described, include Fort Ancient, Serpent Mound and Madisonville (Little Miami River).

Early Political Affairs. The Ohio drainage area came into its own, politically, with the presidential campaign of 1824. The region's two candidates were Henry Clay, of Lexington, Kentucky, and Andrew Jackson, of Nashville, Tennessee. Although neither won in 1824, they both became key figures on the political scene for the next two decades. Clay was Secretary of State in 1825 and tried unsuccessfully for the Presidency in 1832, 1840 and 1844. Jackson was President of the United States from 1829 to 1837. In 1848 the Whig Party ran another military hero, Zachary Taylor. He was also successful; and, like William Henry Harrison, the first candidate from the Northwest Territory, died in office.

Ashland, the Lexington home of Henry Clay has been preserved. Springfield, Taylor's home in Louisville, is still standing.

The one section of this theme that deserves further study is the slavery question, specifically the underground railroad.

Kentucky was a slave state; Indiana, Illinois and Ohio were active in assisting runaway slaves. The name "underground railroad" supposedly dates from 1831, when the Kentucky owner of Tice Davids, a fugitive slave, unsuccessfully pursued him across the Ohio River at Ripley, Ohio. He is supposed to have remarked that Davids "must have gone off into an underground road". The Ripley home of Reverend John Rankin was a key station on the system.

Transportation. From the beginning of the Westward Movement, the Ohio River was the chief highway of immigration. Early settlers found and were quick to use the magnificent system of waterways. During the first six or seven decades, the Ohio served chiefly to populate its own tributaries.

Although interrupted by rapids at Louisville, at high water the Ohio could carry large vessels from Pittsburgh to the Gulf. In 1798 a 120-ton brig was built at Marietta and sailed, via the Mississippi, Gulf of Mexico and Atlantic, to Philadelphia. The construction of keel and flatboats proved to be the safer and more profitable business, however. Transportation companies were formed - the first in Cincinnati in 1814 - and barges were run on regular schedules. By the time steamboats arrived on the Ohio (1811), the river ranked next to the lower Mississippi and the Hudson in waterborne commerce.

The story of steamboat transportation, with the subsequent showboat and panorama, privides one of the most colorful chapters in the history of our country. The Ohio River was its center.

By 1835 some 684 steamboats had been built in the West, of which 677 were built in Pittsburgh, Cincinnati or Louisville. Steamboat traffic was shared by the Ohio's tributaries: the Wabash, the Kentucky, the Tennessee and the Green.

By 1848 a railroad crossed Ohio, linking Cincinnati to Cleveland. In 1852 the Baltimore and Ohio Railroad had pushed across the mountains to Wheeling. From these pioneering efforts developed the great system of today, with 43 railroads and 10,000 miles of track in Ohio alone. The Civil War sounded the death knell, but it was railroading that killed the river trade. When steamers wore out they were never replaced.

Cincinnati

There are several important prehistoric Indian sites in the Cincinnati geographical area. Three important sites relating to Indians who used burial mounds are found near the Little Miami River: Fort Ancient, Fort Hill, and Serpend Mound. All are preserved as Ohio State Memorials; only Fort Hill has not been extensively excavated.

The story of the relationship between the Indians and the early explorers is well told at Fort Recovery, Fort Jefferson, Fort Greenville and Fort St. Claire, all Ohio State Memorials.

Military aspects of the American Revolution are interperted through the George Rogers Clark Memorial in Springfield, Ohio.

Three sites relating to political and military affairs still stand in Cincinnati and are of outstanding value: the house where President William Howard Taft was born and lived until he was 25; the home of Senator George Hunt Pendleton, who secured passage of the Civil Service Reform Bill in 1883; and the stone headquarters building of Civil War Camp Dennison.

At nearby Point Pleasant, the historic house where President Ulysses S. Grant was born is preserved by the Ohio Historical Society. A few miles away, in Georgetown, Ohio, the schoolhouse Grant attended as a youth is preserved.

THE WABASH-CENTRAL INDIANA GEOGRAPHIC AREA

Indians occupied this area for over 15,000 years and left behind many sites in the Wabash-Central Indiana area, our only record of these people.

Early Explorers and Settlements. There is little doubt that the honor of leading the first European expedition into the Ohio drainage area belongs to La Salle. He came here in 1669, although there is much doubt about his exact route. The French, in Canada near the Great Lakes by mid-1600's, favored the Maumee-Wabash River routes to connect the Ohio with Lake Erie. By 1720 they had established military and fur trading posts at present Fort Wayne, Lafayette and Vincennes.

Consideration should be given to the story of the early French along the Wabash River.

Advance of the Frontier. Tippecanoe Battlefield State Memorial, Indiana, interprets the advance of the frontier and early Indian relations in the Wabash region. The Indiana Territory Capitol at Vincennes relates to the development of the Northwest Territory.

George Rogers Clark Memorial in Vincennes has recently been taken over by the National Park Service and is being developed as a national historical park, commemorating and interpreting both the battle and the Northwest Territory.

Transportation. In 1843 Indiana completed the Wabash and Erie Canal, extending from Toledo, through Fort Wayne and Peru, to Terre Haute.

Early Political Affairs. William Henry Harrison's famous "Log Cabin and Hard Cider" campaign of 1840 featured the first candidate from the territory northwest of the Ohio. "Grouseland," his Vincennes home from 1804 to 1812, still stands.

APPENDIX K

ATTACHMENT D

DEVELOPMENT PROGRAM FORMULATION

TABLES

APPENDIX K

ATTACHMENT D

DEVELOPMENT PROGRAM FORMULATION TABLES

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TABLE 1

POPULATION BY ECONOMIC SUBAREAS, 1960-2020

Economic Subarea	1960	1980	2000	2020
	(Thousands of Persons)			
A. Allegheny	1,075	1,221	1,424	1,629
B. Monongahela	556	607	686	774
C. Pittsburgh SMSA	2,405	2,654	3,087	3,415
D. Beaver	864	971	1,179	1,423
E. Upper Ohio	701	745	856	994
F. Muskingum	1,040	1,326	1,662	2,051
G. Kanawha, Little Kanawha	899	1,063	1,265	1,480
H. Ohio-Huntington	532	600	687	788
I. Scioto	1,113	1,561	2,086	2,704
J. Guyandotte, Big Sandy, Little Sandy	464	401	378	357
K. Ohio-Cincinnati	1,310	1,566	1,886	2,237
L. Little Miami, Great Miami	1,419	1,817	2,352	2,960
M. Licking, Kentucky, Salt	723	851	1,096	1,399
N. Ohio-Louisville	853	1,142	1,474	1,823
O. Ohio-Evansville	559	701	867	1,048
P. Green	393	457	598	776
Q. White	1,783	2,366	3,116	3,976
R. Wabash	1,362	1,739	2,235	2,810
S. Cumberland	1,219	1,534	2,026	2,623
TOTAL	19,270	23,322	28,960	35,267

TABLE 2

MAJOR LAND USE BY ECONOMIC SUBAREAS, 1959

Economic Subarea	Total Area (1,000 Acres)	Water		Urban & Built-Up		Cropland		Pastureland		Forest Land		Other Land	
		Area (1,000 Acres)	Percent of Total	Area (1,000 Acres)	Percent of Total	Area (1,000 Acres)	Percent of Total	Area (1,000 Acres)	Percent of Total	Area (1,000 Acres)	Percent of Total	Area (1,000 Acres)	Percent of Total
A. Allegheny	7,574	88	1.2	302	4.0	1,332	17.6	732	9.7	4,322	57.0	798	10.5
B. Monongahela	4,168	41	1.0	139	3.3	529	12.7	907	21.8	2,334	56.0	218	5.2
C. Pittsburgh SMSA	1,971	25	1.3	355	18.0	470	23.9	260	13.2	606	30.7	255	12.9
D. Beaver	1,855	18	1.0	219	11.8	617	33.3	197	10.6	564	30.4	240	12.9
E. Upper Ohio	3,287	35	1.1	184	5.6	575	17.5	711	21.6	1,503	45.7	279	8.5
F. Muskingum	5,175	86	1.7	306	5.9	1,749	33.8	1,074	20.7	1,325	25.6	635	12.3
G. Kanawha, Little Kanawha	9,190	73	.8	233	2.5	824	9.0	1,764	19.2	6,148	66.9	148	1.6
H. Ohio-Huntington	3,826	48	1.2	145	3.8	599	15.6	626	16.4	2,214	57.9	194	5.1
I. Scioto	4,002	23	.6	223	5.6	2,520	63.0	494	12.3	638	15.9	104	2.6
J. Guyandotte, Big Sandy, Little Sandy	3,806	7	.2	92	2.4	152	4.0	222	5.8	3,091	81.2	242	6.4
K. Ohio-Cincinnati	2,657	30	1.1	294	11.1	828	31.2	601	22.6	770	29.0	134	5.0
L. Little Miami, Great Miami	4,165	16	.4	360	8.6	2,694	64.7	496	11.9	521	12.5	78	1.9
M. Licking, Kentucky, Salt	7,887	50	.6	182	2.3	1,434	18.2	2,341	29.7	3,329	42.2	551	7.0
N. Ohio-Louisville	2,403	42	1.7	136	5.7	687	28.6	372	15.5	952	39.6	214	8.9
O. Lower Ohio-Evansville	4,876	117	2.4	177	3.6	1,986	40.7	774	15.9	1,426	29.3	396	8.1
P. Green	5,174	26	.5	122	2.3	1,712	33.1	904	17.5	2,038	39.4	372	7.2
Q. White	8,669	44	.5	467	5.4	4,602	53.1	915	10.5	1,917	22.1	724	8.4
R. Wabash	12,349	88	.7	543	4.4	8,810	71.4	1,159	9.4	1,217	9.8	532	4.3
S. Cumberland	11,387	283	2.5	436	3.8	2,095	18.4	1,801	15.8	5,874	51.6	898	7.9
TOTAL	104,421	1,140	1.0	4,915	4.7	34,215	32.8	16,350	15.7	40,789	39.1	7,012	6.7

TABLE 3

STUDY AREA EMPLOYMENT AND LABOR FORCE, 1960-2020

Industry Category	1960	1980	2000	2020
		(Thousands of Persons)		
Agriculture, forestry and fisheries	428.6	210.8	169.8	186.1
Mining:	172.5	142.3	137.7	136.2
Coal mining	(136.8)	(96.5)	(74.3)	(67.6)
Other mining	(35.7)	(45.8)	(63.4)	(68.6)
Construction	357.0	489.7	931.9	1,246.3
Manufacturing:	2,026.1	2,423.6	2,988.1	3,328.5
Lumber and wood products, furniture and fixtures	(101.4)	(150.0)	(223.6)	(304.9)
Primary metals	(358.9)	(220.7)	(177.7)	(143.2)
Fabricated metal products	(153.5)	(224.7)	(349.8)	(451.4)
Machinery except electrical	(203.7)	(315.2)	(421.4)	(459.1)
Electrical machinery	(237.3)	(385.3)	(556.9)	(656.0)
Transportation equipment (except motor vehicles)	(61.9)	(73.5)	(67.2)	(58.9)
Motor vehicles	(89.8)	(103.9)	(95.1)	(81.5)
Other durable goods	(186.5)	(209.1)	(245.6)	(248.7)
Food and kindred products	(169.4)	(162.9)	(155.0)	(140.0)
Textile mill products	(20.7)	(22.5)	(22.9)	(23.0)
Apparel and finished products	(71.2)	(108.9)	(180.5)	(236.8)
Printing, publishing and allied products	(112.8)	(146.5)	(174.6)	(197.3)
Chemicals and allied products	(107.9)	(119.7)	(114.6)	(106.9)
Other nondurable goods	(151.1)	(180.7)	(203.2)	(220.8)
Transportation, communications and utilities	441.7	531.5	634.5	709.9
Wholesale and retail trade	1,144.3	1,575.5	1,879.2	1,986.8
Finance, insurance and real estate	207.7	324.4	405.7	541.7
Services	1,252.4	1,962.2	2,937.5	4,527.6
Government	259.0	399.0	677.8	1,044.5
Nonclassifiable	229.9	181.2	238.2	350.3
TOTAL EMPLOYMENT	6,519.2	8,240.2	11,000.4	14,057.9
Unemployment	418.1	416.0	556.2	702.6
CIVILIAN LABOR FORCE	6,937.3	8,656.2	11,556.6	14,760.5
Armed Forces	85.4	76.1	71.2	67.0
TOTAL LABOR FORCE	7,022.7	8,732.3	11,627.8	14,827.5

TABLE 4

STUDY AREA OUTPUT BY INDUSTRY, 1960-2020

Industry Category	1960	1980	2000	2020
		(Millions of 1960 Dollars)		
Agriculture, forestry and fisheries	4,595.0	4,928.9	6,114.9	8,752.3
Mining:	2,481.7	4,948.2	9,434.7	15,453.5
Coal mining	(1,391.3)	(2,862.5)	(5,147.4)	(8,505.2)
Other mining	(1,090.4)	(2,085.7)	(4,287.3)	(6,948.3)
Construction	7,269.8	15,712.8	32,728.1	56,862.4
Manufacturing:	48,940.5	94,555.3	175,633.1	300,678.1
Lumber and wood products, furniture and fixtures	(1,278.0)	(2,355.7)	(4,455.7)	(7,528.6)
Primary metals	(9,729.0)	(11,083.1)	(16,701.8)	(22,609.4)
Fabricated metal products	(3,496.2)	(6,730.8)	(13,496.4)	(22,550.1)
Machinery, except electrical	(4,150.7)	(9,223.0)	(17,448.2)	(27,446.4)
Electrical machinery	(4,559.7)	(11,090.5)	(23,231.5)	(39,217.6)
Transportation equipment (except motor vehicles)	(1,475.9)	(3,759.1)	(6,968.3)	(12,384.8)
Motor vehicles	(3,373.0)	(8,133.1)	(15,860.1)	(28,942.0)
Other durable goods	(3,172.9)	(5,942.5)	(11,518.2)	(19,587.1)
Food and kindred products	(6,518.6)	(12,110.8)	(22,593.6)	(40,004.0)
Textile mill products	(245.5)	(445.3)	(780.4)	(1,349.7)
Apparel and finished products	(706.7)	(1,353.0)	(2,796.7)	(4,562.7)
Printing, publishing and allied products	(1,327.7)	(2,765.8)	(5,293.9)	(9,600.6)
Chemicals and allied products	(3,935.4)	(9,015.3)	(17,768.1)	(34,093.1)
Other nondurable goods	(4,971.2)	(10,547.3)	(16,720.2)	(30,802.0)
Transportation, communications and utilities	6,517.0	12,060.9	23,310.5	41,359.5
Wholesale and retail trade	10,232.1	21,667.0	41,840.5	70,149.9
Finance, insurance and real estate	8,868.5	21,303.5	43,133.9	83,296.7
Services	9,011.8	18,312.6	35,742.8	71,712.7
TOTAL OUTPUT	97,916.4	193,489.2	367,938.5	648,265.1

TABLE 5

MUNICIPAL AND INDUSTRIAL WATER SUPPLY DEMANDS BY HYDROLOGIC SUBBASIN, 1960-2020

Hydrologic Subbasin	1960 Municipal	1960 Industrial	1960 Total	1980 Municipal	1980 Industrial	1980 Total	2000 Municipal	2000 Industrial	2000 Total	2020 Municipal	2020 Industrial	2020 Total
	(Million Gallons Per Day)											
Allegheny	215.5	277.7	493.2	278.9	380.4	659.3	356.5	555.5	912.0	500.0	845.0	1,345.0
Monongahela	141.7	4,717.5	4,859.2	168.8	5,575.7	5,744.5	220.0	7,201.5	7,421.5	302.0	10,033.0	10,335.0
Beaver	83.9	970.3	1,054.2	110.0	1,224.0	1,334.0	153.5	1,680.5	1,834.0	221.0	2,443.0	2,664.0
Muskingum	86.0	71.8	157.8	146.6	121.9	268.5	214.5	198.5	413.0	298.2	313.8	612.0
Little Kanawha	.7	6.6	7.3	1.0	9.6	10.6	1.3	14.1	15.4	1.9	20.0	21.9
Kanawha	45.0	1,488.3	1,533.3	68.3	2,046.5	2,114.8	107.0	2,828.9	2,935.9	170.1	4,081.0	4,251.1
Guyandotte	4.8	.2	5.0	4.9	.3	5.2	5.2	.5	5.7	6.0	.6	6.6
Little Sandy	.2	.1	.3	.3	.1	.4	.3	.2	.5	.3	.3	.6
Big Sandy	10.9	51.1	62.0	11.2	73.3	84.5	12.0	111.2	123.2	13.1	175.0	188.1
Scioto	81.0	55.3	136.3	135.2	110.8	246.0	198.8	192.0	390.8	268.9	333.5	602.4
Little Miami	11.8	1.5	13.3	18.8	2.5	21.3	26.2	3.7	29.9	33.6	5.5	39.1
Great Miami	130.6	149.7	280.3	197.1	244.2	441.3	277.5	363.5	641.0	376.0	548.3	924.3
Licking	8.2	0	8.2	13.5	.8	14.3	22.3	1.4	23.7	40.0	2.4	42.4
Kentucky	27.0	3.1	30.1	36.5	7.7	44.2	63.9	14.4	78.3	144.7	26.1	170.8
Salt	2.8	2.3	5.1	4.5	3.0	7.5	8.0	4.8	12.8	16.1	9.7	25.8
Green	15.1	4.1	19.2	21.6	10.0	31.6	41.2	15.8	57.0	81.6	30.0	111.6
Wabash	242.0	215.6	457.6	416.0	380.0	796.0	638.9	655.1	1,294.0	963.5	1,166.5	2,130.0
Cumberland	66.2	45.9	112.1	118.1	80.0	198.1	200.0	132.5	332.5	353.9	229.7	583.6
Upper Ohio	86.1	638.1	724.2	111.6	745.9	857.5	148.5	960.1	1,108.6	204.5	1,320.1	1,524.6
Ohio-Huntington	29.5	361.9	391.4	41.7	524.5	566.2	56.3	825.0	881.3	78.0	1,356.7	1,434.7
Ohio-Cincinnati	121.0	47.3	168.3	167.9	74.7	242.6	219.1	119.4	338.5	279.5	209.0	488.5
Ohio-Louisville	100.4	36.5	136.9	157.8	69.9	227.7	213.6	119.6	333.2	266.4	212.3	478.7
Ohio-Evansville	45.9	26.8	72.7	74.2	44.0	118.2	107.5	66.7	174.2	157.3	118.8	276.1
TOTAL	1,556.3	9,171.7	10,728.0	2,304.5	11,729.8	14,034.3	3,292.1	16,064.9	19,357.0	4,776.6	23,480.3	28,256.9

TABLE 6

LIVESTOCK AND RURAL DOMESTIC WATER SUPPLY DEMANDS BY ECONOMIC SUBAREA, 1960-2020

Economic Subarea	Livestock Present	Livestock 1980	Livestock 2000	Livestock 2020	Rural Farm Domestic Present	Rural Farm Domestic 1980	Rural Farm Domestic 2000	Rural Farm Domestic 2020	Rural Non-Farm Domestic Present	Rural Non-Farm Domestic 1980	Rural Non-Farm Domestic 2000	Rural Non-Farm Domestic 2020
	(Million Gallons Per Day)											
A. Allegheny	4.47	3.96	6.85	9.58	1.43	1.15	1.36	1.59	44.8	50.1	53.7	59.3
B. Monongahela	3.12	1.70	4.10	6.50	1.40	1.25	1.35	1.45	31.0	39.0	45.2	52.4
C. Pittsburgh SMSA	2.16	1.64	2.32	3.04	.67	.45	.44	.42	36.8	43.0	49.0	54.4
D. Beaver	2.66	1.78	2.80	3.88	.89	.76	.73	.70	24.8	25.2	29.2	33.0
E. Upper Ohio	3.50	1.93	3.69	5.40	1.30	.89	1.05	1.20	19.1	22.7	25.2	28.1
F. Muskingum	8.23	8.06	11.80	15.50	2.58	3.15	2.99	2.52	42.1	42.8	50.6	58.0
G. Kanawha, Little Kanawha	6.35	3.61	7.43	11.30	3.17	2.38	2.52	2.65	43.1	58.3	68.3	78.7
H. Ohio-Huntington	2.63	1.65	3.39	5.12	1.50	.80	.98	1.15	20.2	24.6	27.5	29.9
I. Scioto	6.52	10.33	14.51	18.80	1.87	2.07	2.15	2.20	20.9	22.6	27.5	32.6
J. Guyandotte, Big Sandy, Little Sandy	1.09	.55	1.25	1.93	1.20	.47	.59	.73	28.4	28.6	29.1	30.7
K. Ohio-Cincinnati	3.63	3.33	5.50	7.57	1.68	1.02	1.04	1.06	18.9	22.4	26.6	30.9
L. Little Miami, Great Miami	8.03	13.37	16.80	20.40	2.46	2.93	2.47	2.10	34.4	34.8	43.8	54.4
M. Licking, Kentucky, Salt	8.58	8.60	11.10	13.56	4.73	2.42	2.14	1.83	20.6	37.6	45.4	56.1
N. Ohio-Louisville	2.71	3.49	4.01	4.56	1.29	1.10	.92	.75	14.7	17.3	21.9	27.0
O. Lower Ohio-Evansville	3.87	4.46	6.17	7.80	2.00	1.68	1.47	1.29	17.4	21.6	25.7	29.8
P. Green	5.90	6.22	8.30	10.40	3.29	1.91	1.92	1.92	12.5	23.4	30.2	37.5
Q. White	11.58	16.90	25.00	33.00	4.43	4.61	3.85	3.10	46.1	48.2	60.2	72.8
R. Wabash	15.60	29.05	47.20	65.20	5.93	7.01	6.39	5.93	45.1	49.8	62.4	75.9
S. Cumberland	10.59	8.62	11.70	14.70	6.11	3.02	3.01	2.99	37.1	61.2	72.4	92.9
TOTAL	111.22	129.25	193.92	258.24	47.93	39.07	37.37	35.58	558.0	673.2	793.9	934.4

TABLE 7

IRRIGATION WATER SUPPLY DEMANDS BY ECONOMIC SUBAREA, 1960-2020[1]

Economic Subarea	Estimated Present Use				1980				2000				2020			
	Specialty Crops		Field Crops		Specialty Crops		Field Crops		Specialty Crops		Field Crops		Specialty Crops		Field Crops	
	Avg Yr	Driest Yr	Avg Yr	Driest Yr	Avg Yr	Driest Yr	Avg Yr	Driest Yr	Avg Yr	Driest Yr	Avg Yr	Driest Yr	Avg Yr	Driest Yr	Avg Yr	Driest Yr
	(Thousands of Acre-Feet)															
A. Allegheny	0.2	0.3	-	-	1.2	1.7	0.1	0.1	1.7	2.4	0.1	0.1	2.2	3.1	0.2	0.2
B. Monongahela	.1	.2	-	-	.5	.8	.1	.2	.7	1.2	.1	.2	1.0	1.7	.1	.2
C. Pittsburgh SMSA	.1	.2	-	-	1.0	1.7	.1	.2	1.4	2.4	.1	.2	1.7	2.9	.1	.2
D. Beaver	.3	.4	-	-	.5	.6	.1	.1	.7	.9	.1	.1	1.0	1.3	.1	.5
E. Upper Ohio	.2	.3	-	-	1.1	1.8	.1	.2	1.5	2.4	.1	.2	2.0	3.2	.1	.2
F. Muskingum	1.6	2.1	-	-	2.0	2.7	1.5	2.7	2.8	3.8	9.0	12.1	3.7	5.0	15.6	20.9
G. Kanawha, Little Kanawha	1.3	2.2	-	-	1.7	2.9	.1	.2	2.5	4.3	.1	.2	3.3	4.4	.1	.2
H. Ohio-Huntington	.4	.6	-	-	1.3	2.1	.1	.2	2.0	3.2	.1	.2	2.6	4.1	.1	.2
I. Scioto	.4	.6	-	-	2.0	3.1	9.2	3.1	2.8	4.3	55.0	84.2	3.6	5.5	86.5	132.3
J. Guyandotte, Big Sandy, Little Sandy	.4	.7	-	-	.3	.5	.1	.2	.6	.2	.1	.2	.8	1.4	.1	.2
K. Ohio-Cincinnati	.7	1.0	-	-	1.4	2.0	3.0	4.3	2.7	3.9	6.4	9.2	3.6	5.2	38.9	55.6
L. Little Miami, Great Miami	.4	.7	-	-	2.0	3.3	10.7	17.6	2.9	4.8	63.8	104.6	3.7	6.1	99.8	163.7
M. Licking, Kentucky, Salt	3.1	5.3	-	-	4.3	7.3	12.1	20.6	7.0	11.9	25.4	43.2	10.0	17.0	24.0	40.8
N. Ohio-Louisville	.4	.7	-	-	1.4	2.4	1.4	2.4	2.3	3.9	2.9	4.9	3.0	5.0	9.0	15.1
O. Lower Ohio-Evansville	.8	1.4	-	-	.9	1.6	.1	.2	1.7	3.0	.1	.2	2.3	4.1	5.1	9.0
P. Green	.6	1.1	-	-	1.2	2.1	.1	.2	3.2	5.7	.1	.2	4.6	8.2	.1	.2
Q. White	.8	1.2	-	-	9.6	14.1	10.7	15.7	13.1	19.3	63.6	93.5	16.5	24.3	145.9	214.5
R. Wabash	4.6	6.0	-	-	11.0	14.3	17.9	23.3	15.0	19.5	95.5	124.2	18.7	24.3	245.7	319.4
S. Cumberland	1.8	2.9	-	-	3.1	5.0	.1	.2	6.6	10.6	.1	.2	8.9	14.3	.1	.2
TOTAL	18.2	27.9	12.4[2]	16.8[2]	46.5	70.0	67.6	91.7	71.2	107.7	322.7	477.9	93.2	141.1	671.9	973.7

NOTES: (1) Water requirements for each projection year include present irrigation water use and are based on 75 percent application efficiency. Does not include storage or abnormal transmission losses.

(2) Subarea breakdown not available.

TABLE 8

IRRIGABLE AGRICULTURAL LANDS BY ECONOMIC SUBAREA, 1960-2020[1]

Economic Subarea	Present		1980		2000		2020	
	Specialty Crops	Field Crops	Specialty Crops	Field Crops	Specialty Crops	Field Crops	Specialty Crops	Field Crops
	(Thousands of Acres)							
A. Allegheny	0.4	-	2.0	0.1	3.1	0.1	4.2	0.3
B. Monongahela	.2	-	.8	.1	1.3	.1	1.8	.1
C. Pittsburgh SMSA	.1	-	1.6	.1	2.5	.1	3.3	.1
D. Beaver	.5	-	.8	.1	1.3	.1	1.8	.7
E. Upper Ohio	.3	-	1.8	.1	2.8	.1	3.8	.1
F. Muskingum	2.6	-	3.3	3.1	5.1	17.9	6.9	28.9
G. Kanawha, Little Kanawha	2.1	-	2.8	.1	4.5	.1	6.3	.1
H. Ohio-Huntington	.7	-	2.2	.1	3.7	.2	5.0	.2
I. Scioto	.7	-	3.4	18.8	5.1	110.1	6.7	160.1
J. Guyandotte, Big Sandy, Little Sandy	.6	-	.7	.1	1.0	.1	1.5	.1
K. Ohio-Cincinnati	1.1	-	2.4	6.1	4.9	12.8	6.8	72.0
L. Little Miami, Great Miami	.6	-	3.3	21.9	5.2	127.6	6.9	184.9
M. Licking, Kentucky, Salt	5.2	-	7.6	24.7	12.8	50.8	18.8	44.5
N. Ohio-Louisville	.7	-	2.3	2.8	4.2	5.8	5.7	16.7
O. Lower Ohio-Evansville	1.3	-	1.5	.1	3.1	.1	4.4	9.4
P. Green	1.0	-	2.0	.1	5.8	.1	8.7	.1
Q. White	1.3	-	16.0	21.9	23.8	127.3	31.1	270.2
R. Wabash	7.6	-	18.4	36.5	27.3	191.0	35.2	455.0
S. Cumberland	3.0	-	5.2	.1	12.0	.1	16.8	.1
TOTAL	30.0	20.0[2]	78.1	136.9	129.5	644.5	175.7	1,243.6

NOTES: (1) Economic potential for agricultural irrigation.

(2) Subarea breakdown not available.

TABLE 9

RESIDUAL ORGANIC WASTE LOADS BY HYDROLOGIC SUBBASIN, 1960-2020(1)

Hydrologic Subbasin	1960 Municipal & Commercial	1960 Industrial	1960 Total	1980 Municipal & Commercial	1980 Industrial	1980 Total	2000 Municipal & Commercial	2000 Industrial	2000 Total	2020 Municipal & Commercial	2020 Industrial	2020 Total
	(Thousands of Population Equivalents)											
Allegheny	114.6	61.0	175.6	148.6	91.0	239.6	195.3	140.1	335.4	260.4	216.9	477.3
Monongahela	99.1	37.2	136.3	107.3	49.0	156.3	129.3	72.6	201.9	165.5	97.5	263.0
Beaver	94.1	38.4	132.5	116.6	48.4	165.0	148.6	66.8	215.4	197.6	97.5	295.1
Muskingum	85.9	63.4	149.3	135.2	108.7	243.9	184.7	178.2	362.9	244.2	281.7	525.9
Little Kanawha	1.5	16.5	18.0	1.6	23.9	25.5	2.0	35.0	37.0	2.7	49.7	52.4
Kanawha	46.8	966.6	1,013.4	62.4	1,316.2	1,378.6	90.0	1,878.8	1,968.8	132.2	2,842.6	2,974.8
Guyandotte	2.2	.3	2.5	2.0	.4	2.4	1.9	.5	2.4	1.9	.6	2.5
Little Sandy	.3	0	.3	.3	0	.3	.3	0	.3	.3	0	.3
Big Sandy	7.9	.3	8.2	6.8	.5	7.3	6.5	.9	7.4	6.0	1.3	7.3
Scioto	115.7	136.5	252.2	173.4	267.8	441.2	237.2	460.0	697.2	307.5	795.4	1,102.9
Little Miami	16.8	2.7	19.5	23.8	3.6	27.4	31.3	5.9	37.2	38.5	8.8	47.3
Great Miami	112.3	151.3	263.6	161.6	246.8	408.4	217.5	367.5	585.0	280.4	554.5	834.9
Licking	7.2	1.8	9.0	10.3	4.1	14.4	16.5	7.8	24.3	30.2	15.5	45.7
Kentucky	23.4	19.9	43.3	28.7	40.3	69.0	45.4	73.6	119.0	92.4	135.6	228.0
Salt	5.5	49.1	54.6	7.4	98.9	106.3	11.6	190.2	201.8	21.5	370.1	391.6
Green	16.9	10.3	27.2	20.4	23.6	44.0	36.0	37.7	73.7	68.3	69.6	137.9
Wabash	276.0	294.7	570.7	423.9	518.0	941.9	599.6	875.3	1,474.9	848.4	1,558.2	2,406.6
Cumberland	54.6	54.9	109.5	81.8	96.7	178.5	125.9	164.1	290.0	205.1	284.4	489.5
Upper Ohio	336.2	139.6	475.8	386.3	170.0	556.3	462.8	225.3	688.1	566.6	319.3	885.9
Ohio-Huntington	33.2	15.5	48.7	42.4	22.6	65.0	52.0	35.9	87.9	66.1	59.6	125.7
Ohio-Cincinnati	150.2	195.4	345.6	188.5	301.8	490.3	228.1	453.9	682.0	266.1	714.8	980.9
Ohio-Louisville	83.2	123.9	207.1	116.4	231.8	348.2	152.0	397.2	549.2	181.5	685.4	866.9
Ohio-Evansville	49.0	29.5	78.5	71.2	47.7	118.9	96.2	71.6	167.8	131.2	132.2	263.4
TOTAL	1,732.6	2,408.8	4,141.4	2,316.9	3,711.8	6,028.7	3,070.7	5,738.9	8,809.9	4,114.6	9,291.2	13,405.8

NOTE: (1) Assuming 85 percent removal of BOD.

TABLE 10

RESIDUAL AVERAGE ANNUAL FLOOD DAMAGES BY HYDROLOGIC SUBBASIN, 1965-2020(1)

Hydrologic Subbasin	1965 Downstream	1965 Upstream	1965 Total	1980 Downstream	1980 Upstream	1980 Total	2000 Downstream	2000 Upstream	2000 Total	2020 Downstream	2020 Upstream	2020 Total
	(Thousands of 1965 Dollars)											
Allegheny	1,565	1,158	2,723	2,292	1,447	3,739	3,915	2,041	5,956	6,657	2,826	9,483
Monongahela	1,357	3,584	4,941	2,020	4,445	6,465	3,483	5,993	9,476	5,617	7,916	13,533
Beaver	1,482	702	2,184	2,050	821	2,871	3,307	1,063	4,370	5,375	1,393	6,768
Muskingum	2,748	2,991	5,739	3,621	3,768	7,389	6,682	5,565	12,247	11,641	7,511	19,152
Little Kanawha	137	780	917	143	1,039	1,182	312	1,421	1,733	568	1,956	2,524
Hocking	391	382	773	585	428	1,013	1,125	772	1,897	2,161	1,211	3,372
Kanawha	3,996	3,037	7,033	4,431	4,104	8,535	9,631	5,558	15,189	17,440	7,556	24,996
Guyandotte	10	1,262	1,272	14	1,394	1,408	24	1,672	1,696	41	2,085	2,126
Big Sandy	1,064	1,605	2,669	1,523	1,746	3,269	2,658	2,102	4,760	4,660	2,607	7,267
Scioto	4,042	1,965	6,007	6,443	2,829	9,272	9,800	4,181	13,981	17,552	5,585	23,137
Little Miami	310	412	722	543	630	1,173	917	926	1,843	1,402	1,237	2,639
Great Miami	1,650	2,183	3,833	2,967	3,245	6,212	4,624	4,684	9,308	7,732	6,220	13,952
Licking	660	664	1,324	979	793	1,772	1,399	977	2,376	1,919	1,165	3,084
Kentucky	1,308	750	2,058	1,890	920	2,810	2,980	1,171	4,151	4,730	1,443	6,173
Salt	2,088	242	2,330	3,043	281	3,324	4,151	334	4,485	5,905	383	6,288
Green	2,029	2,179	4,208	2,348	2,478	4,826	2,851	3,062	5,913	3,679	3,844	7,523
Wabash	20,317	16,076	36,393	23,276	21,698	44,974	27,136	29,357	56,493	34,770	37,215	71,985
Cumberland	515	4,314	4,829	643	6,330	6,973	835	7,545	8,380	1,052	9,190	10,242
Minor Tribs	620	8,775	9,395	732	9,878	10,610	1,079	12,561	13,640	1,570	15,252	16,822
Ohio River	11,282	-	11,282	16,499	-	16,499	27,434	-	27,434	44,580	-	44,580
TOTAL	57,571	53,061	110,632	76,042	68,274	144,316	114,343	90,985	205,328	179,051	116,595	295,646

NOTE: (1) Assuming flood control projects in "Going Program" fully effective.

TABLE 11

OUTDOOR RECREATION DEMANDS AND NEEDS BY ECONOMIC SUBAREA, 1960-2020

Economic Subarea	Annual Recreation Days (Millions)	Land Area [1] (1,000 Acres)	Water Area (1,000 Acres)	1960 Demands	1960 Needs	1980 Demands	1980 Needs	2000 Demands	2000 Needs	2020 Demands	2020 Needs
				(Millions of Annual Recreation Days)							
A. Allegheny	9.0	895.4	19.4	11.2	2.2	26.8	17.8	48.8	39.8	70.8	61.8
B. Monongahela	2.5	511.3	3.5	7.0	4.5	16.7	14.2	30.3	27.8	44.0	41.5
C. Pittsburgh SMSA	3.3	16.1	.7	13.0	9.7	31.0	27.7	56.3	53.0	81.7	78.4
D. Beaver	1.8	20.9	7.6	7.6	5.8	18.2	16.4	33.1	31.3	48.0	46.2
E. Upper Ohio	1.7	44.6	1.7	7.5	5.8	17.8	16.1	32.4	30.7	46.9	45.2
F. Muskingum	2.8	153.8	17.2	12.4	9.6	29.6	26.8	53.9	51.1	78.1	75.3
G. Kanawha, Little Kanawha	4.7	681.5	5.3	7.8	3.1	18.6	13.9	33.8	29.1	49.0	44.3
H. Ohio-Huntington	1.7	195.6	12.1	4.3	2.6	10.2	8.5	18.6	16.9	27.0	25.3
I. Scioto	4.7	75.8	7.5	8.2	3.5	19.5	14.8	35.5	30.8	51.5	46.8
J. Guyandotte, Big Sandy, Little Sandy	.4	38.1	1.2	4.8	4.4	11.4	11.0	20.7	20.3	30.0	29.6
K. Ohio-Cincinnati	3.5	27.8	1.1	6.6	3.1	15.7	12.2	28.5	25.0	41.3	37.8
L. Little Miami, Great Miami	5.0	21.0	9.5	11.2	6.2	26.8	21.8	48.7	43.7	70.6	65.6
M. Licking, Kentucky, Salt	.6	250.7	8.2	8.6	8.0	20.6	20.0	37.5	36.9	54.3	53.7
N. Ohio-Louisville	.6	15.6	.2	3.8	3.2	9.0	8.4	16.3	15.7	23.6	23.0
O. Lower Ohio-Evansville	.8	220.9	2.4	4.3	3.5	10.3	9.5	18.7	17.9	27.1	26.3
P. Green	.9	54.3	2.5	4.2	3.3	10.1	9.2	18.3	17.4	26.6	25.7
Q. White	1.0	197.6	5.7	15.1	14.1	35.9	34.9	65.3	64.3	94.6	93.6
R. Wabash	.9	48.1	7.4	16.4	15.5	39.2	38.3	71.3	70.4	103.4	102.5
S. Cumberland	12.4	663.1	134.9	9.7	E 2.7 [2]	23.2	10.8	42.2	29.8	61.1	48.7
TOTAL	58.3	4,132.2	248.1	163.7	105.4	390.6	332.3	710.2	651.9	1,029.6	971.3

NOTES: (1) Amount of water area included in land area.
(2) E - indicates an excess; supply is greater than demand.

TABLE 12

FISHING DEMANDS AND NEEDS BY HYDROLOGIC SUBBASIN, 1980 AND 2020

Hydrologic Subbasin	Resources: Miles of Stream (1,000)	Resources: Ponded Water Area (1,000 Acres)	Resources: Public Fishing Ponded Water Area (1,000 Acres)	Actual Use 1960	Demand 1980	Demand 2020	Needs 1980	Needs 2020
					(Millions of Angler Days)			
Allegheny	3.83	43.45	18.64	1.80	2.43	3.26	0.16	0.45
Monongahela	1.57	13.29	8.84	0.37	0.55	0.93	0.04	0.15
Beaver	0.73	37.11	32.22	0.91	1.26	1.81	0.16	0.50
Muskingum	1.06	27.96	29.59	1.50	2.07	2.84	0.02	0.55
Kanawha, Little Kanawha	10.24	16.27	4.05	0.87	1.31	1.97	E 0.01 [1]	0.36
Guyandotte, Big Sandy, Little Sandy	2.55	1.50	1.19	1.00	0.23	0.19	E 0.18	E 0.22
Scioto	1.38	11.89	4.10	1.50	2.25	3.20	0.37	1.30
Little Miami, Great Miami	1.41	15.42	9.76	1.70	2.70	3.90	0.25	1.30
Licking, Kentucky, Salt	4.80	24.80	4.17	1.40	2.69	4.18	0.13	0.93
Green	3.21	22.34	5.84	1.10	2.22	3.52	0.44	1.40
Wabash	4.48	65.26	36.22	3.60	5.93	8.45	0.03	2.20
Cumberland	5.90	147.43	129.92	3.50	6.65	9.98	1.90	4.90
Ohio River & Minor Tribs	5.14	64.40	118.87	2.51	4.94	7.56	E 0.19	1.03
TOTAL	46.30	491.12	403.41	21.76	35.23	51.79	3.12	14.85

NOTE: (1) E - indicates an excess; supply is greater than demand.

TABLE 13

HUNTING DEMANDS AND NEEDS BY HYDROLOGIC SUBBASIN, 1980 AND 2020

Hydrologic Subbasin	Resources: Total Land (Million Acres)	Resources: Public Hunting Land (Million Acres)	Actual Use 1960	Demand 1980	Demand 2020	Needs 1980	Needs 2020
				(Millions of Hunter Days)			
Allegheny	7.51	1.13	4.17	4.52	4.68	0.34	0.50
Monongahela	4.40	0.47	1.80	2.35	2.64	0.51	0.80
Beaver	1.82	0.10	0.51	0.55	0.68	E 0.08(1)	0.05
Muskingum	4.79	0.17	0.57	0.67	0.78	0.08	0.19
Kanawha, Little Kanawha	9.40	0.72	2.16	2.52	2.61	0.25	0.34
Guyandotte, Big Sandy, Little Sandy	3.84	0.04	0.98	0.84	0.79	0.04	E 0.01
Scioto	3.94	0.12	0.53	0.66	0.86	0.08	0.28
Little Miami, Great Miami	4.72	0.01	0.83	1.06	1.38	0.21	0.53
Licking, Kentucky, Salt	8.79	0.21	1.30	1.60	1.89	0.33	0.62
Green	5.86	0.01	0.70	0.83	0.98	0.12	0.27
Wabash	21.04	0.14	3.81	4.43	5.23	0.60	1.40
Cumberland	11.49	0.64	1.20	1.50	1.70	0.30	0.50
Ohio River & Minor Tribs	16.34	0.45	3.10	3.98	4.37	0.63	1.02
TOTAL	103.94	4.21	21.66	25.51	28.59	3.41	6.49

NOTE: (1) E - indicates an excess; supply is greater than demand.

TABLE 14

OHIO BASIN WATERWAYS CAPABILITY AND DEMAND FOR WATER TRANSPORT IN BILLION TON-MILES ANNUALLY

Waterway	Capability of Waterways with Going Program In Place	1965 Traffic	Projected Demands: Gross 1980	Gross 2000	Gross 2020	Net 1980	Net 2000	Net 2020
Existing:								
Ohio	34.0	23.27	42.0	76.0	127.0	8.0	42.0	93.0
Allegheny	.09	.06	.07	.1	.13	-	.01	.04
Monongahela	1.8	1.79	1.9	2.2	2.5	.1	.4	.7
Kanawha	.9	.71	1.4	2.7	4.2	.5	1.8	3.3
Kentucky	.03	.02	.06	.12	.21	.03	.09	.18
Green-Barren	2.0	1.03	1.9	3.2	4.1	-	1.2	2.1
Cumberland	3.8	.45	.8	1.7	3.2	.02*	.1*	.2*
Total	42.62	27.33	48.13	86.02	141.34	8.65	45.50	99.52
Potential:								
Lake Erie-Ohio River[1]	-	-	0.6	3.1	3.5	0.6	3.1	3.5
Big Sandy-Levisa Fork	-	-	.25	.45	.65	.25	.45	.65
Wabash	-	-	.32	.97	1.9	.32	.97	1.9
Total	-	-	1.17	4.52	6.05	1.17	4.52	6.05
Grand total	42.62	27.33	49.30	90.54	147.39	9.82	50.12	105.57

* Upper river estension only.

[1] *Data are for 61-mile Ohio Basin section only.*

TABLE 15

SUMMARY OF CORPS OF ENGINEERS PROJECTS IN THE GOING PROGRAM[1]

Hydrologic Subbasin	Reservoirs: Number	Reservoirs: Drainage Area Controlled (Sq Mi)	Reservoirs: Flood Control Storage (1,000 Ac-Ft)	Reservoirs: Cost ($ Million)	Major Local Protection Projects: Number	Major Local Protection Projects: Length of Levees & Walls (Miles)	Major Local Protection Projects: Length of Channel Improvements (Miles)	Major Local Protection Projects: Cost ($ Million)	Small Local Protection Projects: Number	Small Local Protection Projects: Cost ($ Million)	Total Cost ($ Million)
Allegheny	10	5,317	1,712.8	213.9	14	20.3	34.7	39.3	11	1.14	254.3
Monongahela	2	1,618	429.0	29.3	3	0.7	12.3	18.4	7	0.32	48.0
Beaver	4	1,016	302.9	59.8	2	-	6.4	4.1	-	-	63.9
Muskingum	16	5,060	1,603.7	76.3	4	5.0	10.6	10.1	2	0.06	86.5
Little Kanawha	-	-	-	-	-	-	-	-	1	0.03	-
Hocking	1	33	17.6	3.0	-	-	-	-	-	-	3.0
Kanawha	3	5,905	1,252.1	113.7	3	-	10.9	1.9	4	0.25	115.8
Guyandotte	1	540	181.7	82.7	1	-	-	0.2	-	-	82.9
Big Sandy	4	842	339.3	88.5	1	0.4	-	1.1	3	0.46	90.1
Scioto	5	1,965	571.4	100.0	-	-	-	-	-	-	100.0
Little Miami	2	579	359.1	49.8	-	-	-	-	-	-	49.8
Great Miami[2]	2	461	247.6	43.9	-	-	-	-	-	-	43.9
Licking	1	826	438.5	28.9	-	-	-	-	-	-	28.9
Kentucky	5	1,663	910.4	88.3	2	0.7	Minor	0.2	3	0.27	88.8
Salt	-	-	-	-	1	8.1	-	0.4	3	0.05	0.5
Green	4	2,779	2,051.9	79.7	1	-	64.0	(3)	2	0.08	79.8
Wabash	6	3,016	1,321.0	74.9	17	184.6	5.0	37.1	4	0.32	112.3
Cumberland	6	17,598	5,031.0	367.5	5	6.3	6.6	7.0	1	0.58	375.1
Minor Tribs	4	437	214.3	60.2	5	15.8	53.6	13.4	15	2.00	75.6
Ohio River	-	-	-	-	27	130.3	2.4	125.9	-	-	125.9
TOTAL	76	49,655	16,984.3	1,560.4	86	372.2	206.5	259.1	56	5.56	1,825.1

NOTES: (1) Includes those Corps of Engineers projects constructed, under construction, and in advanced planning as of July 1965.

(2) Does not include 5 detention type flood control reservoirs and local protection projects at 12 communities constructed by the Miami Conservancy District in the Great Miami subbasin. The 5 reservoirs have a capacity of 841,000 acre-feet for flood control and the local protection projects include approximately 53 miles of levees and 43 miles of channel improvement.

(3) Cost of channel improvement included in reservoir costs.

TABLE 16

SUMMARY OF WATERSHED PROJECTS IN THE GOING PROGRAM[1]

Hydrologic Subbasin	Number of Projects	Area of Watersheds (Sq Mi)	Number of Dams	Drainage Area Controlled (Sq Mi)	Storage (Ac Ft): Sediment	Storage (Ac Ft): Floodwater[2]	Storage (Ac Ft): Other Uses[3]	Storage (Ac Ft): Total	Surface Area (Acres): Sediment Pool	Surface Area (Acres): Flood Pool[2]	Channel Improvements (Miles)	Estimated Flood Prevention Cost ($1,000)	Flood Plain Area (Acres)
Allegheny	4	492	27	180	1,241	26,298	25,863	53,402	296	6,050	31	3,488	12,096
Monongahela	7	124	30	46	1,043	7,764	780	9,587	195	785	16	3,339	2,328
Beaver	2	120	10	64	281	7,831	2,505	10,617	33	1,575	-	1,726	540
Muskingum	1	188	9	39	406	6,294	2,767	9,467	107	944	33	2,030	10,300
Little Kanawha	2	64	6	20	316	4,040	147	4,503	40	213	6	984	1,168
Hocking	2	286	31	121	6,593	18,426	2,252	27,271	517	2,660	28	5,237	14,063
Kanawha	5	87	19	21	385	4,188	525	5,098	85	459	23	2,072	2,437
Great Miami	2	80	11	26	266	5,450	101	5,817	33	380	22	1,562	2,650
Licking	1	27	2	2	35	330	-	365	14	57	4	42	817
Kentucky	1	24	-	-	-	-	-	-	-	-	6	165	336
Salt	1	37	12	11	304	2,163	-	2,467	70	258	21	343	1,253
Green	12	1,293	89	509	12,855	73,592	18,075	104,522	2,520	8,577	206	12,968	52,419
Wabash	16	1,253	78	350	8,180	55,072	19,019	82,271	1,819	8,781	306	14,850	48,301
Cumberland	6	306	24	151	2,472	18,582	3,674	24,728	323	2,084	48	4,200	8,385
Minor Tribs	12	999	92	334	9,659	54,174	9,112	72,945	2,190	6,850	211	13,175	47,952
TOTAL	74	5,380	440	1,874	44,036	284,204	84,820	413,060	8,242	39,673	961	66,181	205,045

NOTES: (1) Includes those Soil Conservation Service projects authorized as of July 1965.

(2) To crest of emergency spillway.

(3) Storage for beneficial uses other than flood prevention.

TABLE 17

NON-FEDERAL IMPOUNDMENTS(1)

Subbasin and Reservoir	Drainage Area Controlled (Sq Mi)	Purpose(2)	Total Storage (Ac Ft)	Surface Area (Acres)
ALLEGHENY				
Edinboro Lake	16.2	R		240
Lake Irene	1.4	R		255
Riley Run Dam	0.8	M		232
Yellow Creek Park Dam	52.6	R		740
Two Lick Creek Dam	74	MP		500
Indian Lake	14.9	R		750
Beaver Run	43.2	M		1,125
Bull	1.2	M		245
Tamarack Lake	5.4	FH		556
Piney	957	P,R		690
Quemahoning	9.2	M	32,766	900
Lake Chautauqua	188.4			13,570
MONONGAHELA				
Deep Creek Lake		P	106,060	3,900
High Point Lake	3.7	FH		342
Lake Somerset		FH		253
Lake of Woods		R	1,000	96
Lake Lynn		P,R	72,300	1,729
BEAVER				
Moraine State Park Dam	53	R		3,200
Pymatuning	160	F,LF,P	194,000	16,420
Upper Crooked Creek Dam	13.6	R		235
Lake Latonka	12.7	M		320
Deer Creek	36.5	M	3,100	313
Evans Lake	10.3	M	8,497	566
Lake Girard	12.2	M	2,760	185
Lake Hamilton	14.1	M	2,270	104
Liberty Lake	3.8	M	1,825	99
McKelvey Lake	8.5	M	3,310	125
Meander Creek	86.5	M	30,675	2,010
Lake Milton	276	LF	21,600	1,685
Pine Lake	4.4	M	2,653	474
MUSKINGUM				
Barberton	26.8	M	670	200
Buckeye Lake	49.2	R	19,940	2,853
Clear Fork	34	M	10,760	997
Lake Dorothy	13.8	M	1,058	100
Knox Lake	31	R		495
Nimisila	19.3	M	9,500	211
Chippewa Lake		R		322
Mohawk Lake	6.1	R	7,900	500
East		M,R		201
Turkey Foot Lake		M,R		318
Salt Fork	160	F,M,R		6,900
HOCKING				
Dow Lake	7.3	R	1,884	153
Lake Logan	14.8	R		340
KANAWHA				
Byllesby	1,310	P	3,540	335
Gatewood	15.4	P	3,630	162
Claytor Lake	2,382	P	232,000	4,540
Little River	337	P	1,020	113
Plum Orchard Lake	2,625	R		202
Steven Branch Lake	2,447	R	8,000	303
Buckley Water Company	16,000	M	1,228	110
Flat Top Lake	4,272	R		225
Hawks Nest	6,880	P	6,100	
SCIOTO				
Julian Griggs	1,052	M,R	3,450	363
Hammertown Lake	3.1	M,R	4,600	176
Hargus Lake	6.5	R	2,800	146
Hoover	190	M,R	60,480	2,825
O'Shaughnessy	997	M,R	13,125	829
Rock Fork	115	R	34,100	2,020
Lake White	37.4	R	3,734	337
Lake Choctaw	25	R	2,800	260
LITTLE MIAMI				
Cowan Lake	51.3	R	12,000	720
Shawnee Lake	10.4	R	2,550	190
GREAT MIAMI				
Englewood	646	F	312,000	Dry
Germantown	275	F	106,000	Dry
Huffman	632	F	167,000	Dry
Taylorsville	1,155	F	186,000	Dry
Lockington	261	F	70,000	Dry
Acton Lake	101.7	R	9,400	625
Indian Lake	110	R	45,900	5,065
Kiser Lake	8.7	R	3,261	386
Lake Loramie	70	R	13,000	807
Richmond Water Works		M	6,190	175
Lake Santee	4.63	R	2,710	250
LICKING				
Campbell County Lake		R	3,500	200
Falmouth		R		200
Williamstown Lake		R		305
KENTUCKY				
Blue Grass Ordnance		M	1,530	
Herrington Lake		M,P,R		1,000
Campton Lake	0.5	R	1,000	35
Fishpond Lake	0.6	R	1,500	40
Beech Creek Lake	1.9	M,R	1,400	60

TABLE 17 (Cont'd)

NON-FEDERAL IMPOUNDMENTS[1]

Subbasin and Reservoir	Drainage Area Controlled (Sq Mi)	Purpose[2]	Total Storage (Ac Ft)	Surface Area (Acres)
SALT				
Lake Simpson		M,R	7,000	250
Beaver Creek Lake		R	3,500	165
Guist Creek Lake		M,R		325
GREEN				
Campbellsville		M	2,485	
WABASH				
Grand Lake St. Marys	118	R	90,000	12,800
Bradford Woods Lake		R	1,200	110
Cordry Lake		R,M	6,320	169
Geist		M	21,000	1,800
Glendale		M	20,400	1,313
Grandview Lake		R		324
Holiday Lake	5.6	R	2,435	168
Huntingburg City Lake	2.03	M,R	2,000	180
Ken-Ray Lake	1.88	R	2,083	84
Lake Greenwood		M,R		800
Lake Lemon	63.5	M	13,350	1,536
Lamb Indian Creek	9.34	R	7,250	309
Morse	216	M	21,000	1,430
Muncie Water Works	17	M		1,275
Princess East Lake	31.6	R	7,000	
Lake Vermilion	298	M	5,472	655.9
Lake Charleston		M		358.6
Lake Mattoon	55.6	M	10,400	765.4
Lake Sara	11.8	M	13,800	586
Stephen A. Forbes Lake		R,WL		585
CUMBERLAND				
Cranks Creek Lake	25	R	10,000	200
MINOR TRIBUTARIES				
Grant Lake	25.5	R	1,190	221
Lake Hope	10	R	1,506	120
Jackson Lake	19	R	1,700	243
J. C. Bacon Dam	15.7	M		409
Tycoon Lake	1.4	R	2,000	204
Barnesville	5.6	M	1,954	98
Guilford Lake	10.9	R	2,510	326
Salem	0.8	M	2,086	115
Greenbo Lake		R		225
Doe Run Lake		R		200
Pennyrile Lake		R	1,000	55
Lake Brashear		M,R	9,000	857
Batesville Water Works	4.4	M	2,100	200
Salida Lake	5.7	M	1,030	74
Versailles State Park Lake		M,R	2,970	266
Lake of Egypt	34	CW	42,550	2,400
Open Pond				554.3
Eldorado	3.1	M	1,074	97.8
Harrisburg New North	5.4	M	2,763	202.5
Horeshoe Lake		R,WL		2,400
Mermet Lake		R		690

NOTES: (1) Limited to those projects which have a total storage of 1,000 acre-feet or greater and/or have a surface area of 200 acres or greater.

(2) Purpose: F Flood control
FH - Fish propagation
M - Water supply
CW - Cooling water
LF - Low flow augmentation
R - Recreation
P - Power
WL - Wildlife
MP - Mechanical water power

TABLE 18

NON-FEDERAL LOCAL FLOOD PROTECTION PROJECTS

Subbasin and Project Location	County	Status
ALLEGHENY		
Windber, Pa., Paint Creek and Seese Run	Somerset	Completed
Canadohta Lake, Pa., Mill Run	Crawford	Completed
Tionesta, Pa., Council Run	Forest	Completed
Brockway, Pa., Little Toby Creek	Jefferson	Completed
Smethport, Pa., Marvin and Potato Creeks	McKean	Completed
Coudersport, Pa., Allegheny River and Mill Creek	Potter	Completed
Warren, Pa., Glade Run	Warren	Completed
Meadville, Pa., Mill Run	Crawford	Under Construction
Warren, Pa., Indian Hollow Run	Warren	Under Construction
MONONGAHELA		
Greensburg, Pa., Jacks Run	Westmoreland	Completed
Jeannette, Pa., Brush Creek	Westmoreland	Completed
Jeannette, Pa., Bull Run Dam	Westmoreland	Completed
Rockwood, Pa., Casselman River and Coxes Creek	Somerset	Under Construction
Confluence, Pa., Youghiogheny and Casselman Rivers and Laurel Hill Creek	Somerset	Under Construction
BEAVER		
West Middlesex, Pa., Hogback Run	Mercer	Completed
HOCKING		
Hocking River and Rush Creek Levees, Ohio	Franklin	Completed
Lancaster, Ohio, Hocking River	Franklin	Completed
SCIOTO		
Columbus, Ohio, Scioto River	Franklin	Completed
Blacklick Estates Levees, Ohio Blacklick Creek	Franklin	Completed
GREAT MIAMI		
Piqua, Ohio, Great Miami River	Miami	Completed
Troy, Ohio, Great Miami River	Miami	Completed
Tipp City, Ohio, Great Miami River	Miami	Completed
Miami Ohio Villa, Great Miami River	Montgomery	Completed
Dayton, Ohio, Great Miami River	Montgomery	Completed
Moraine, Ohio, Great Miami River	Montgomery	Completed
West Carrollton, Ohio, Great Miami River	Montgomery	Completed
Miamisburg, Ohio, Great Miami River	Montgomery	Completed
Franklin, Ohio, Great Miami River	Warren	Completed
Middletown, Ohio, Great Miami River	Butler	Completed
Dicks Creek, Ohio	Butler	Completed
Hamilton, Ohio, Great Miami River	Butler	Completed
WABASH		
Indianapolis, Ind., White River	Marion	Completed
Indianapolis, Ind., Eagle Creek	Marion	Under Construction
Numerous agricultural levees completed by local interests which provide various degrees of protection		
OHIO RIVER MINOR TRIBUTARIES		
Darlington, Pa., Little Beaver Creek	Beaver	Completed
Shawneetown, Ill., Ohio River	Gallatin	Completed

TABLE 19

CORPS OF ENGINEERS RESERVOIRS IN THE GOING PROGRAM

Subbasin and Reservoir[1]	Jul 65[2] Status	Purpose[3]	Drainage Area Controlled (Sq Mi)	Storage Capacity (1,000 Ac Ft) Minimum	Conservation	Power	Flood Control	Total	Area of Pool (Acres) Minimum	Conservation	Power	Total
ALLEGHENY												
Allegheny	UC	F,Q,R	2,180	24.0	216.0w[4] 549.0s[4]		940.0w 607.0s	1,180.0	1,900	12,080		21,180
Conemaugh River	C	F,R	1,351	4.0			270.0	274.0	300			6,280
Crooked Creek	C	F,R	277	4.5			89.4	93.9	350			1,940
E Br Clarion	C	F,Q,R	72	1.0	44.6w 64.3s		38.7w 19.0s	84.3	90	1,160		1,370
Loyalhanna	C	F,R	290	2.0			93.3	95.3	210			3,280
Mahoning Creek	C	F,R	340	4.5			69.7	74.2	170			2,370
Muddy Creek	AP	F	61	-			19.6	19.6	-			-
Tionesta	C	F,R	478	7.8			125.6	133.4	480			2,770
Union City	AP	F	222	-			47.6	47.6	-			-
Woodcock Creek	AP	F,Q,R	46	0.8	0.3w 3.9s		18.9w 15.3s	20.0	100			775
MONONGAHELA												
Tygart	C	F,N,R	1,184	9.7	0w 99.9s		278.0w 178.1s	287.7	620	1,740		3,430
Youghiogheny	C	F,Q,R	434	5.2	97.8w 149.3s		151.0w 99.5s	254.0	450	2,840		3,570
BEAVER												
Berlin	C	F,M,Q,R	249	1.8	33.6w 56.6s		55.8w 32.8s	91.2	240	3,590		5,500
Mosquito Creek	C	F,M,Q,R	97	2.0	69.1w 80.4s		33.0w 21.7s	104.1	700	7,850		8,900
Shenango	UC	F,Q,R	589(5)	11.5	0w 29.9s		180.9w 151.0s	192.4	1,910	3,560		11,090
West Branch	UC	F,M,Q,R	80.5	3.8	41.7w 52.9s		33.2w 22.0s	78.7	570	2,650		3,240
MUSKINGUM												
Atwood	C	F,R	70	23.6			26.1	49.7	1,540			2,460
Beach City	C	F,R	300	1.7			70.0	71.7	420			6,150
Bolivar	C	F	502	-			149.6	149.6	-			-
Charles Mill	C	F,R	216	7.4			80.6	88.0	1,350			6,050
Clendening	C	F,R	70	26.5			27.5	54.0	1,800			2,620
Dillon	C	F,R	748	13.1	0w 4.4s		260.9w 256.5s	274.0	1,330	1,560		10,280
Dover	C	F,R	1,397(6)	1.0			202.0	203.0	350			10,100
Leesville	C	F,R	48	19.5			17.9	37.4	1,000			1,470
Mohawk	C	F	1,501(7)	-			285.0	285.0	-			-
Mohicanville	C	F	269	-			102.0	102.0	-			-
N Br Kokosing	AP	F,R	44.5	0.7			14.2	14.9	98			1,140
Piedmont	C	F,R	84	34.5			32.2	66.7	2,310			3,270
Pleasant Hill	C	F,R	199	13.5			74.2	87.7	850			2,600
Senecaville	C	F,R	121	43.5			45.0	88.5	3,550			5,170
Tappan	C	F,R	71	35.1			26.5	61.6	2,350			3,100
Wills Creek	C	F,R	844	6.0			190.0	196.0	900			11,450
HOCKING												
Tom Jenkins	C	F,M,R	32.8	3.5	5.8		17.6	26.9	394	664		1,192
KANAWHA												
Bluestone	C	F,R	4,565	30.9	0w 5.6s		600.1w 549.5s	631.0	1,800	1,970		9,180
Summersville	UC	F,Q,R	803	23.0	0w 163.4s		390.8w 277.4s	413.8	407	2,723		4,920
Sutton	C	F,Q,R	537	4.1	0w 60.1s		261.2w 201.1s	265.3	270	1,520		3,875
GUYANDOTTE												
R. D. Bailey	AP	F,Q,R	540	22.0	0w 12.2s		181.7w 169.5s	203.7	440	630		2,850
BIG SANDY												
Dewey	C	F,R	207	12.3	0w 4.9s		81.0w 76.1s	93.3	880	1,100		3,340
Fishtrap	UC	F,Q,R	395	10.6	0w 27.2s		153.8w 126.6s	164.4	590	1,131		2,631
J. W. Flannagan	UC	F,Q,R	222	12.0	38.6w 55.1s		95.1w 78.6s	145.7	310	1,143		2,098
North Fork Pound River	UC	F,R	17.6	1.9	0w 1.3s		9.4w 8.1s	11.3	106	154		349
SCIOTO												
Big Darby	UC	F,R,	448	7.4			121.6	129.0	661			4,538
Deer Creek	UC	F,R,	278	6.4	0w 14.6s		96.1w 81.5s	102.5	727	1,277		4,046
Delaware	C	F,Q,R	381	8.4	0w 5.6s		123.6w 118.0s	132.0	950	1,300		8,700
Paint Creek	UC	F,R	573	8.9			136.1	145.0	710			4,760
Salt Creek	AP	F,R	285	6.3	0w 11.5s		94.0w 88.3s	100.3	833	1,233		3,969
LITTLE MIAMI												
Caesar Creek	AP	F,M,Q,R	237	13.3	80.4w 88.7s		148.5w 140.2s	242.2	700	2,830		6,110
East Fork	AP	F,M,Q,R	342	19.0	65.2w 157.8s		210.6w 118.0s	294.8	820	2,160		4,600
GREAT MIAMI												
Brookville	UC	F,M,R	379	55.6	89.3w 128.4s		214.7w 175.6s	359.6	2,250	5,260		7,790
Clarence J. Brown	UC	F,Q,R	82	9.9	20.9w 27.0s		32.9w 26.8s	63.7	1,010	2,120		2,720

TABLE 19 (Cont'd)

CORPS OF ENGINEERS RESERVOIRS IN THE GOING PROGRAM

Subbasin and Reservoir[1]	Jul 65[2] Status	Purpose[3]	Drainage Area Controlled (Sq Mi)	Storage Capacity (1,000 Ac Ft) Minimum	Storage Capacity (1,000 Ac Ft) Conservation	Storage Capacity (1,000 Ac Ft) Power	Storage Capacity (1,000 Ac Ft) Flood Control	Storage Capacity (1,000 Ac Ft) Total	Area of Pool (Acres) Minimum	Area of Pool (Acres) Conservation	Area of Pool (Acres) Power	Area of Pool (Acres) Total
LICKING												
Cave Run	UC	F,Q,R	826	147.3	28.3w 75.3s		438.5w 391.5s	614.1	6,790	8,270		14,870
KENTUCKY												
Booneville	AP	F,Q,R	686	37.7	31.3w 70.3s		404.0w 365.0s	473.0	1,900	3,064		6,980
Buckhorn	C	F,R	408	10.3	0w 21.7s		157.7w 136.0s	168.0	550	1,230		3,610
Carr Fork	UC	F,Q,R	58	11.8	4.2w 11.7s		31.7w 25.2s	47.7	530	710		1,120
Eagle Creek	AP	F,M,Q,R	292	15.4	55.1w 151.6s		197.0w 100.5s	267.5	950	3,600		8,180
Red River	AP	F,M,Q,R	219	12.0	54.0w 65.0s		120.0w 109.0s	186.0	600	2,110		3,140
GREEN												
Barren River	C	F,M,R	940	45.9	0.7w 210.5s		768.6w 558.8s	815.2	3,414	10,000		20,150
Green River	UC	F,Q,R	682	98.1	64.5w 146.0s		560.6w 479.1s	723.2	5,070	8,200		19,100
Nolin River	C	F,M,Q,R	703	39.3	161.6w 292.5s		408.5w 277.6s	609.4	2,070	5,800		14,530
Rough River	C	F,R	454	20.2	0w 99.8s		314.2w 214.4s	334.4	1,700	5,100		10,260
WABASH												
Cagles Mill	C	F,R	295	27.1			201.0	228.1	1,400			4,840
Huntington	UC	F,R	702	4.1	0w 8.4s		149.0w 140.6s	153.1	500	900		7,900
Mansfield	C	F,R	216	16.2	0w 33.1s		116.6w 83.5s	132.8	1,100	2,060		3,910
Mississinewa	UC	F,R	809	23.3	0w 51.9s		345.1w 293.2s	368.4	1,280	3,180		12,830
Monroe	C	F,M,R	441	22.3	159.9		258.8	441.0	3,280	10,750		18,450
Salamonie	UC	F,R	553	13.1	0w 47.6s		250.5w 202.9s	263.6	976	2,860		9,340
CUMBERLAND												
Barkley	UC	P,F,N,R	17,598	610.0		0w 259.0s	1,472.0w 1,213.0s	2,082.0	45,210		57,920	93,430
Center Hill	C	P,F,R	2,195	838.0		492.0	762.0	2,092.0	14,590		18,220	23,060
Dale Hollo	C	P,F,R	935	857.0		496.0	353.0	1,706.0	21,880		27,700	30,990
J. Percy Priest	UC	P,F,R	865	268.0		34.0w 90.0s	350.0w 260.0s	652.0	10,570		14,200	22,720
Laurel	UC	P,R	282	250.6		185.0	-	435.6	4,200		6,060	6,060
Wolf Creek	C	P,F,R	4,789	1,853.0		2,142.0	2,094.0	6,089.0	35,820		50,250	63,530
LITTLE SANDY												
Grayson	UC	F,Q,R	196	15.4	3.3w 14.0s		100.3w 89.6s	119.0	1,050	1,500		3,620
MILL CREEK, OHIO												
West Fork	C	F,R	29.5	1.5			9.9	11.4	183			557
TWELVEPOLE CREEK, W VA												
Beech Fork	AP	F,R	78	4.2	0w 4.9s		33.3w 28.4s	37.5	450	720		1,830
East Lynn	UC	F,R	133	11.7	0w 5.5s		70.8w 65.3s	82.5	823	1,005		2,351

NOTES: (1) Includes projects constructed, under construction, or in advanced planning as of July 1965.

(2) Status: C-Completed, UC-Under Construction, AP-Advanced Planning.

(3) Purpose: F-Flood Control, Q-Water Quality, M-Water Supply, P-Power, R-Recreation, N-Navigation.

(4) w-winter, s-summer.

(5) Includes 158 square miles controlled by Pymatuning Reservoir, a non-Federal project.

(6) Includes 620 square miles controlled by Atwood, Bolivar and Leesville Reservoirs.

(7) Includes 684 square miles controlled by Charles Mill, Pleasant Hill and Mohicanville Reservoirs.

(8) Includes 8,898 square miles controlled by Center Hill, Dale Hollow, J. Percy Priest, Laurel and Wolf Creek Reservoirs.

TABLE 20

WATERSHED PROJECTS IN THE GOING PROGRAM

Subbasin and Watershed Project	Purpose (1)	Project Area (Sq Mi)	Number of Structures	Drainage Area Controlled (Sq Mi)	Storage (Ac Ft)				Channel Improvements (Miles)
					Sediment	Floodwater	Other Uses	Total	
ALLEGHENY									
Mill Run, Pa	FP,F&WL	12.2	4	8.7	99	2,776	2,716	5,591	
Sandy Creek, Pa	FP,F&WL	65.6	2	58.8	133	5,349	19,875	25,357	
Conewango Creek, NY	FP,F&WL	297.0	13	68.3	657	10,616	1,700	12,973	30.9
Ischua Creek, NY	FP,F&WL,R	117.0	8	43.8	352	7,557	1,572	9,481	.15
MONONGAHELA									
Little Youghiogheny, Md	FP	41.0	6	14.4	223	3,003		3,226	1.6
Dunlap Creek, Pa	FP,F&WL	16.5	4	8.6	151	1,227	780	2,158	.2
Polk Creek, W Va	FP	11.4	8	6.6	253	1,528		1,781	
Upper Deckers Creek, W Va	FP	31.1	5	14.6	389	1,651		2,040	7.2
Salem Fork, W Va	FP	8.3	7	2.1	27	355		382	
Shooks Run, W Va	FP	3.0							.7
Peck's Run, W Va	FP	12.8							6.0
BEAVER									
Saul-Mathay, Pa	FP	6.1	2	3.0	29	585		614	
Little Shenango River, Pa	FP,R	113.7	8	60.8	252	7,246	2,505	10,003	
MUSKINGUM									
Chippewa, Ohio	FP,R	188.0	9	39.0	406	6,294	2,767	9,467	33.2
LITTLE KANAWHA									
Bond's Creek, W Va	FP,F&WL	14.7	1	.5	11	86	147	244	5.8
Saltlick Creek, W Va	FP	49.5	5	19.7	305	3,954		4,259	
HOCKING									
Rush Creek, Ohio	FP,R,M&I	236.7	23	96.4	6,238	9,716	2,252	18,206	22.1
Upper Hocking, Ohio	FP	49.1	8	24.4	355	8,710		9,065	5.5
KANAWHA									
Brush Creek, W Va	FP,M&I	34.8	14	16.6	280	3,238	153	3,671	5.9
Dave's Fork-Christian's Fork, W Va	FP	6.5	3	2.4	43	502		545	1.2
Marlin Run, W Va	FP	1.6	1	1.2	15	272		287	
Back Creek, Va	FP	34.9							11.1
Big Ditch Run, W Va	FP,R	9.0	1	1.2	47	176	372	595	5.0
GREAT MIAMI									
Dick's Creek-Little Muddy Creek, Ohio	FP	69.7	6	22.4	184	5,161		5,345	17.7
East Fork Buck Creek, Ohio	FP,F&WL	10.3	5	3.0	82	289	101	472	3.7
LICKING									
Twin Creek, Ky	FP	27.2	2	1.7	35	330		365	3.7
KENTUCKY									
Red River, Ky	FP	24.0							6.0
SALT									
Plum Creek, Ky	FP	37.0	12	11.0	304	2,163		2,467	21.0
GREEN									
Beaver Creek, Ky	FP	52.9	1	33.5	529	3,749		4,278	
Big Muddy Creek, Ky	FP	101.8	5	39.5	1,255	5,924		7,179	17.5
Big Reddy Creek, Ky	FP	41.2	2	11.1	199	1,425		1,624	9.3
Caney Creek, Ky	FP,R,M&I	152.0	10	68.2	2,217	10,075	258	12,550	20.0
East Fork Pond River, Ky	FP	218.2	17	115.3	2,559	13,794		16,353	53.4
Line Creek, Tenn & Ky	FP	63.0	5	30.8	678	8,217		8,895	38.0
Mud River, Ky	FP,R,M&I	375.0	26	131.8	2,910	17,795	16,137	36,842	15.6
Short Creek, Ky	FP	38.0	3	14.3	351	2,268		2,619	4.5
Upper Green River, Ky	FP	38.0	5	3.7	76	646		722	12.0
Upper North Fork Rough River, Ky	FP	40.0	2	5.5	94	1,028		1,122	10.0
Valley Creek, Ky	FP,M&I,R	90.6	4	20.4	769	3,750	1,600	6,119	
West Fork Pond River, Ky	FP,M&I	82.7	9	35.2	1,218	4,923	80	6,221	25.0
WABASH									
Upper Wabash, Ohio	FP	126.0	3	19.3	370	2,101		2,471	38.2
Busseron, Ind	FP,R,M&I	236.8	26	112.1	3,778	21,829	14,029	39,636	52.9
Stucker Fork, Ind	FP	184.0	16	67.9	1,091	10,980		12,071	25.6
Dewitt Creek, Ind	FP	14.1	2	6.2	168	695		863	2.3
Bachelor Run, Ind	FP	36.7							20.6
Kickapoo Creek, Ind	FP	38.6							9.3
Lattas Creek, Ind	FP	55.9							22.4
Little Wea Creek, Ind	FP	18.7							8.6
Prairie Creek-Vigo, Ind	FP	29.8	3	15.1	635	2,063		2,698	4.9
Prairie Creek-Daviess, Ind	FP,R	138.5	11	38.6	1,275	3,771	174	5,220	33.5
Elk Creek, Ind	FP,F&WL	28.2	8	7.3	39	841	494	1,374	10.8
French Lick, Ind	FP,F&WL	34.2	4	11.9	267	2,892	1,302	4,461	5.1
Boggs Creek, Ind	FP	63.7	2	49.2	141	4,658		4,799	8.2
Twin Rush, Ind	FP,M&I	43.9	3	22.2	416	5,242	3,020	8,678	9.9
Mill Creek-Fulton, Ind	FP	90.0							
Scattering Fork, Ill	FP	114.1							

TABLE 20 (Cont'd)

WATERSHED PROJECTS IN THE GOING PROGRAM

Subbasin and Watershed Project	Purpose[1]	Project Area (Sq Mi)	Number of Structures	Drainage Area Controlled (Sq Mi)	Storage (Ac Ft)				Channel Improvements (Miles)
					Sediment	Floodwater	Other Uses	Total	
CUMBERLAND									
Buck Creek, Ky	FP	120.1	3	89.1	975	6,740		7,715	10.0
North Fork, Little River, Ky	FP,M&I,F&WL	58.7	4	26.8	490	4,934	3,019	8,443	
Proctor Creek, Tenn	FP	13.2							5.2
Pine Creek, Tenn	FP,F&WL,M&I	26.2	4	6.1	77	1,466	655	2,198	6.0
Meadow Creek, Ky	FP	15.4							7.4
Jennings Creek, Tenn	FP	72.1	13	29.3	930	5,442		6,372	19.0
OHIO MINOR TRIBS									
Middle Fork of Anderson, Ind	FP,R	108.4	6	52.8	583	9,816	434	10,833	34.4
Canoe Creek, Ky	FP	119.8	10	13.6	420	1,682		2,102	29.5
Humphrey-Clanton, Ky	FP	107.1	5	26.1	528	4,529		5,057	25.0
Little Kentucky River, Ky	FP,R	71.2	6	29.1	604	5,163	1,699	7,466	
Upper Grave Creek, W Va	FP,M&I	7.7	7	2.0	39	387	129	555	3.6
West Fork Duck Creek, Ohio	FP,R,M&I	106.8	8	39.9	2,618	8,838	4,937	16,393	19.9
Crab Orchard, Ky	FP	151.4	13	35.8	651	3,987		4,638	31.6
Cypress Creek, Ky	FP,R	50.7	3	3.0	103	578	389	1,070	6.0
Donaldson, Ky	FP,R	73.5	7	33.0	500	5,161	543	6,204	31.1
Upper Tradewater, Ky	FP	93.7	8	53.0	2,189	7,459		9,648	13.9
Little Cache, Ill	FP	70.3	5	25.9	892	3,447		4,339	16.0
Harmon Creek, W Va & Pa	FP,F&WL	38.0	14	19.7	532	3,127	981	4,640	

NOTE: (1) FP - Flood prevention
M&I - Municipal and industrial water supply
R - Recreation
F&WL - Fish and wildlife development

TABLE 21

COMPLETED AND UNDER CONSTRUCTION HYDROELECTRIC POWER PLANTS

Subbasin and Name of Plant	Location	Owner	Installed Capacity (MW)
Allegheny			
Piney	Clarion, Pa.	Pennsylvania Electric Co.	28.8
Monongahela			
Lake Lynn	Lake Lynn, Pa.	West Penn Power Co.	51.2
Deep Creek	Sines, Md.	Pennsylvania Electric Co.	19.2
Kanawha-Little Kanawha			
Winfield	Winfield, W. Va.	Kanawha Valley Power Co.	14.8
Marmet	Marmet, W. Va.	Kanawha Valley Power Co.	14.4
London	Handley, W. Va.	Kanawha Valley Power Co.	14.4
Alloy	Alloy, W. Va.	Union Carbide Carbon Co.	102.0
Claytor	Radford, Va.	Appalachian Power Co.	75.0
Buck	Ivanhoe, Va.	Appalachian Power Co.	8.5
Byllesby	Byllesby, Va.	Appalachian Power Co.	21.6
Licking-Kentucky-Salt			
Dix Dam	High Bridge, Ky.	Kentucky Utilities Co.	28.3
Wabash			
Norway	Norway, Ind.	North Indiana Public Service	6.7
Oakdale	Yeoman, Ind.	North Indiana Public Service	11.0
Ohio-Louisville			
Ohio Falls	Louisville, Ky.	Louisville Gas & Electric Co.	80.3
Markland	Markland, Ind.	Indiana Public Service Co.	81.0
Cumberland			
Wolf Creek	Creelsboro, Ky.	Corps of Engineers	270.0
Dale Hollow	Celina, Tenn.	Corps of Engineers	54.0
Great Falls	Rock Island, Tenn.	Tennessee Valley Authority	31.9
Center Hill	Buffalo Valley, Tenn.	Corps of Engineers	135.0
Old Hickory	Old Hickory, Tenn.	Corps of Engineers	100.0
Cheatham	Billsburg, Tenn.	Corps of Engineers	36.0
Barkley	Grand Rivers, Ky.	Corps of Engineers	130.0
J. Percy Priest	Nashville, Tenn.	Corps of Engineers	28.0
Cordell Hull	Carthage, Tenn.	Corps of Engineers	100.0
Laurel	Corbin, Ky.	Corps of Engineers	61.0

TABLE 22

STREAMFLOW CHARACTERISTICS FOR SELECTED GAGING STATIONS

Subbasin and Location	Period of Record	Drainage Area (Sq Mi)	Average Discharge (cfs)	Average Discharge (csm)	Floods - 1000 cfs, csm: Peak of Record 1000 cfs	Peak of Record csm	2 Year 1000 cfs	2 Year csm	50 Year 1000 cfs	50 Year csm	100 Year 1000 cfs	100 Year csm	Low Flows - cfs, csm: Minimum cfs	Minimum csm	7 Day-10 Year cfs	7 Day-10 Year csm	Yield-Storage 1000 Acre-Feet Required per csm[2] .2	.6	.8
ALLEGHENY																			
Allegheny River, Red House, NY	1903-59	1,690	2,792	1.65	49.1	(29.1)[1]	25.0	(14.8)	51.0	(30.2)	57.0	(33.7) (N)	80.0	(.047)	115.0	(.068)	.03	.18	.28
Allegheny River, Franklin, Pa	1914-59	5,982	10,320	1.72	13.8	(23.1)	88.0 63.0	(14.7) (10.5)	175.0 110.0	(29.3) (18.4)	195.0 121.0	(32.6) (N) (20.1) (M)	334.0	(.056)	470.0	(.079)	.05	.16	.25
Allegheny River, Kittanning, Pa	1904-28; 1934-59	8,973	15,710	1.75	269.0	(30.0)	136.0 110.0	(15.2) (12.3)	268.0 193.0	(29.9) (21.5)	300.0 213.0	(33.4) (N) (23.7) (M)	570.0	(.064)	750.0	(.084)	.03	.15	.21
Allegheny River, Natrona, Pa	1938-59	11,410	19,490	1.71	238.0	(20.9)	175.0 120.0	(15.3) (10.5)	344.0 179.0	(29.9) (15.7)	385.0 192.0	(33.7) (N) (16.8) (M)	922.0	(.081)	890.0	(.078)	.05	.16	.21
MONONGAHELA																			
Monongahela River, Lock 15, Hoult, W Va	1938-59	2,388	4,120	1.72	91.5	(38.3)	64.0 39.7	(26.8) (16.6)	138.0 83.0	(57.8) (34.8)	158.0 94.5	(66.2) (N) (39.6) (M)	33.0	(.014)	99.0	(.043)	.04	.17	.25
Big Piney Run, Salisbury, Pa	1932-63	24.5	37.9	1.55	6.85	(274.0)	1.1	(44.0)	5.5	(220.0)	6.8	(272.0) (N)	0.08	(.003)	-	-	-	-	-
BEAVER																			
Mahoning River, Youngstown, Ohio	1921-62	899	844	0.94	17.6	(20.0)	14.0 8.7	(15.6) (9.7)	30.3 16.8	(33.7) (18.7)	35.5 19.5	(39.5) (N) (21.7) (M)	28.0	(.031)	-	-	.06	.40	-
Beaver River, Wampum, Pa	1932-59	2,235	2,365	1.06	50.1	(22.4)	27.0 20.9	(12.1) (9.4)	56.0 43.3	(25.0) (19.4)	64.0 49.5	(28.6) (N) (22.1) (M)	74.0	(.033)	-	-	.06	.40	-
MUSKINGUM																			
Walhonding River, Nellie, Ohio	1921-59	1,502	1,457	0.97	43.8	(29.2)	18.25	(12.2)	57.0	(38.0)	67.0	(44.6) (0)	3.3	(.022)	-	-	-	-	-
Muskingum River nr Coshocton, Ohio	1936-62	4,847	4,855	1.00	78.7	(16.2)	41.0	(8.5)	125.0	(25.8)	147.5	(30.5) (0)	342.0	(.071)	462.0	(.095)	.01	.17	.35
LITTLE KANAWHA																			
Little Kanawha River, Palestine, W Va	1939-59	1,515	2,100	1.39	53.0	(35.0)	52.8	(34.9)	55.4	(36.6)	61.0	(40.3) (N)	36.0	(.024)	-	-	.01	.17	.27
HOCKING																			
Hocking River, Athens, Ohio	1915-62	944	978	1.04	30.4	(32.2)	14.8	(15.7)	32.6	(34.5)	37.0	(39.2) (N)	9.0	(.010)	36.0	(.038)	.08	.30	-
KANAWHA																			
Kanawha River, Charleston, W Va	1939-59	10,419	14,320	1.38	216.0	(20.7)	-	-	-	-	-	-	1,030.0	(.099)	1,285.0	(.123)	.04	.12	.19
S Fk New River, Jefferson, NC	1924-59	207	411	1.98	52.8	(256.5)	5.5	(26.6)	21.4	(103.3)	27.9	(134.7) (N)	65.0	(.314)	89.0	(.43)	-	-	-
GUYANDOTTE, TWELVEPOLE CREEK, BIG SANDY, LITTLE SANDY, TYGARTS CREEK																			
Levisa Fork, Paintsville, Ky	1915; 1928-62	2,143	2,385	1.11	69.7	(32.5)	41.7	(19.5)	92.9	(43.4)	108.0	(50.4) (N)	8.4	(.004)	15.0	(.002)	.04	.39	-
Tug Fork, Kermit, W Va	1934-62	1,185	1,332	1.12	61.3	(51.7)	27.8	(23.4)	71.0	(59.9)	84.0	(70.9) (N)	23.0	(.019)	26.0	(.022)	.04	.39	-
Big Sandy River, Louisa, Ky	1938-62	3,892	4,228	1.09	89.4	(22.9)	53.8	(13.8)	140.0	(36.0)	164.0	(42.1) (N)	Not determined		59.0	(.015)	.04	.35	-
Little Sandy River, [illegible]	1938-62	402	484	1.20	24.[illegible]	(60.9)	11.9	(29.6)	29.4	(73.1)	34.6	(86.1) (N)	1.5	(.004)	2.7	(.007)	-	-	-
[illegible]	[illegible]	242	304	1.26	14.8	(61.2)	7.7	(31.8)	20.7	(85.5)	24.2	(100.0) (N)	No flow		-	-	-	-	-
[illegible]	[illegible]	[illegible]	1,573	1.28	40.4	(33.0)	24.2	(19.8)	52.0	(42.5)	59.8	(48.8) (N)	3.6	(.003)	20.0	(.016)	.05	.25	-
[illegible]	[illegible]	[illegible]	326	1.12	22.0	(75.6)	8.25	(28.4)	21.6	(74.3)	25.4	(87.3) (N)	No flow		-	-	-	-	-
[illegible]																			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	68.2	(42.0)	27.5	(16.9)	74.0	(45.6)	86.0	(52.9) (N)	42.0	(.026)	57.8	(.036)	.12	.63	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	144.0	(37.4)	53.2	(13.8)	156.0	(40.6)	187.6	(48.7) (N)	160.0	(.042)	184.5	(.048)	.10	.55	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.2	(74.3)	1.5	(21.4)	3.96	(56.6)	-	- (N)	No flow		No flow		-	-	-
[illegible]																			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(70.4)	33.3 21.9	(27.9) (18.3)	77.0 64.0	(64.6) (53.5)	85.0 75.0	(71.1) (N) (62.7) (M)	27.0	(.023)	42.0	(.035)	.05	.34	.60

[illegible] stream regulation)
[illegible]

[illegible] indicated flow in cfs per square mile. Example: Allegheny River at Redhouse requires 300 acre-feet [illegible] a constant flow of 338 cfs requires 507,000 acre-feet of storage.

TABLE 22 (Cont'd)

STREAMFLOW CHARACTERISTICS FOR SELECTED GAGING STATIONS

Subbasin and Location	Period of Record	Drainage Area (Sq Mi)	Average Discharge (cfs)	Average Discharge (csm)	Floods - 1000 cfs, csm: Peak of Record 1000 cfs	Peak of Record csm	2 Year 1000 cfs	2 Year csm	50 Year 1000 cfs	50 Year csm	100 Year 1000 cfs	100 Year csm	Low Flows - cfs, csm: Minimum cfs	Minimum csm	7 Day-10 Year cfs	7 Day-10 Year csm	Yield-Storage 1000 Acre-Feet Required per csm[2] .2	.6	.8
GREAT MIAMI																			
Mad River, Springfield, Ohio	1904-06; 1914-59	485	680	1.40	30.5	(62.9)[1]	10.0 6.3	(20.6) (20.6)	28.3 21.3	(58.4) (43.9)	33.9 26.1	(69.9) (N) (53.8) (M)	30.0	(.062)	115.0	(.237)	-	-	-
Great Miami River, Taylorsville, Ohio	1921-62	1,155	995	0.86	31.4	(27.2)	18.1 17.5	(15.7) (15.2)	33.5 29.1	(29.0) (25.2)	37.5 31.4	(32.5) (N) (27.2) (M)	30.0	(.026)	46.0	(.040)	.06	.45	-
Great Miami River, Dayton, Ohio	1929-62	2,513	2,083	0.83	60.9	(24.2)	44.3 33.5	(17.6) (13.3)	102.9 60.1	(40.9) (23.9)	112.9 64.2	(44.9) (N) (25.5) (M)	78.0	(.031)	175.0	(.070)	.03	.42	-
Great Miami River, Hamilton, Ohio	1931-62	3,639	3,203	0.88	352.0 (1913)	(96.8)	58.2 48.9	(16.0) (13.4)	134.3 98.1	(37.0) (27.0)	149.9 110.3	(41.2) (N) (30.3) (M)	100.0	(.028)	281.0	(.077)	.02	.35	-
Whitewater River, Brookville, Ind	1923-62	1,239	1,274	1.03	81.8	(66.0)	34.0 31.0	(27.4) (25.0)	126.0 90.0	(103.3) (72.6)	155.0 117.0	(125.0) (N) (94.5) (M)	49.0	(.040)	82.0	(.066)	.10	.33	-
LICKING																			
Licking River, Farmers, Ky	1938-62	831	1,076	1.29	24.0	(28.9)	13.4 7.0	(16.1) (8.4)	27.0 7.0	(32.5) (8.4)	30.9 7.0	(37.2) (N) (8.4) (M)	0.7	(.0008)	3.1	(.004)	-	.24	.45
S Fk Licking River, Cynthiana, Ky	1933-62	621	751	1.21	35.3	(56.8)	19.7	(31.7)	58.0	(93.4)	69.9	(112.6) (N)	0.3	(.0005)	0.7	(.001)	.10	.47	.72
Licking River, Catawba, Ky	1914-20; 1928-62	3,300	4,131	1.25	86.3	(26.2)	50.0 45.5	(15.1) (13.8)	101.0 91.1	(30.6) (27.6)	112.0 101.0	(34.3) (N) (30.6) (M)	2.5	(.0008)	10.3	(.003)	.07	.33	.50
KENTUCKY																			
N Fk Kentucky River, Jackson, Ky	1938-62	1,101	1,293	1.18	53.5	(48.6)	29.7	(27.0)	75.0	(68.1)	86.1	(78.2) (N)	No flow		2.2	(.002)	.05	.30	-
Kentucky River nr Winchester, Ky	1907-62	3,955	5,223	1.32	92.4	(23.4)	61.5	(15.5)	108.0	(27.3)	117.0	(29.6) (N)	(est) 10.0	(.003)	33.0	(.008)	.08	.38	.44
Kentucky River, Frankfort, Ky	1925-62	5,412	7,023	1.30	115.0	(21.2)	70.0 63.0	(12.9) (11.6)	128.0 123.0	(23.7) (22.7)	142.0 138.0	(26.2) (N) (25.5) (M)	-	-	112.0	(.021)	.04	.25	.42
Kentucky River, Lockport, Ky	1925-62	6,180	8,247	1.33	123.0	(19.9)	75.0	(12.1)	157.0	(25.4)	175.0	(28.4) (N)	Not determined		163.0	(.026)	-	-	-
SALT																			
Rolling Fork, Boston, Ky	1938-62	1,299	1,720	1.32	41.3	(31.8)	30.0	(23.1)	65.0	(50.1)	74.5	(57.4) (N)	0.4	(.0003)	1.3	(.001)	.05	.34	.58
GREEN																			
Green River, Greensburg, Ky	1939-62	736	1,086	1.48	60.6	(82.3)	22.8	(31.0)	48.2	(65.5)	54.8	(74.5) (N)	0.4	(.0005)	1.7	(.002)	-	.33	.53
Barren River, Bowling Green, Ky	1938-62	1,848	2,464	1.33	85.0	(46.0)	33.5	(18.1)	81.0	(43.8)	92.0	(49.8) (N)	44.0	(.024)	53.0	(.029)	.07	.31	.53
Green River, Woodbury, Ky	1936-62	5,403	7,979	1.46	205.0	(39.0)	67.5	(12.5)	128.0	(23.7)	143.0	(26.5) (N)	200.0	(.037)	241.0	(.045)	-	-	-
WABASH																			
Wabash River, Bluffton, Ind	1930-59	506	403	0.80	11.8	(23.4)	7.0	(13.8)	17.4	(33.4)	20.2	(39.9) (N)	3.9	(.008)	4.7	(.009)	.10	.58	-
Wabash River, Wabash, Ind	1923-59	1,733	1,511	0.87	49.6	(28.6)	23.8	(13.7)	58.7	(33.9)	67.6	(39.0) (N)	17.0	(.010)	26.0	(.015)	.10	.60	-
Wabash River, Logansport, Ind	1923-59	3,751	3,317	0.88	89.8	(23.9)	42.5	(11.3)	96.8	(25.8)	110.8	(29.5) (N)	97.0	(.026)	190.0	(.051)	.07	.49	-
Wabash River, Lafayette, Ind	1923-59	7,247	6,401	0.88	131.0	(18.1)	54.0	(7.5)	122.0	(16.9)	139.0	(19.2) (N)	265.0	(.037)	535.0	(.074)	.06	.40	-
Wabash River, Montezuma, Ind	1927-59	11,100	9,492	0.86	184.0	(16.6)	67.0	(6.0)	192.0	(17.3)	226.0	(20.4) (N)	510.0	(.046)	775.0	(.070)	.03	.42	-
Wabash River, Terre Haute, Ind	1927-59	12,200	10,440	0.86	189.0	(15.5)	68.0	(5.6)	192.0	(15.7)	225.0	(18.5) (N)	690.0	(.057)	900.0	(.074)	-	-	-
Embarrass River, Ste. Marie, Ill	1909-13; 1914-59	1,540	1,227	0.80	44.8	(29.0)	17.0	(11.0)	67.0	(43.5)	88.0	(57.1) (N)	1.0	(.0006)	16.0	(.011)	.10	.49	-
White River, Indianapolis, Ind	1930-59	1,627	1,411	0.87	37.2	(22.9)	20.1	(12.4)	62.0	(38.1)	76.4	(47.0) (N)	6.8	(.004)	105.0	(.065)	.10	.57	-
Eel River, Bowling Green, Ind	1931-59	844	854	1.01	34.0	(40.3)	18.5	(21.9)	56.0	(66.4)	68.0	(80.6) (N)	11.0	(.013)	17.0	(.020)	.07	.38	-
E Fk White River, Seymour, Ind	1927-59	2,333	2,431	1.04	78.5	(33.6)	37.0	(15.9)	123.0	(52.7)	154.0	(66.0) (N)	84.0	(.036)	155.0	(.066)	.10	.49	.70
E Fk White River, Shoals, Ind	1909-16; 1923-59	4,954	5,458	1.10	160.0	(29.3)	42.0 37.5	(8.5) (7.6)	116.0 109.0	(23.4) (22.0)	135.0 128.0	(27.3) (N) (25.8) (M)	44.0	(.009)	222.0	(.045)	.07	.47	.77
Wabash River, Mt Carmel, Ill	1927-59	28,600	26,980	0.94	305.0	(11.3)	147.0 132.0	(5.1) (4.9)	395.0 374.0	(13.8) (13.9)	458.0 441.0	(16.0) (N) (16.3) (M)	1,620.0	(.060)	2,250.0	(.083)	-	-	-
Little Wabash River, Carmi, Ill	1939-59	3,090	2,587	0.84	39.4	(12.8)	14.5	(4.7)	54.0	(17.5)	64.5	(20.9) (N)	0.6	(.0002)	5.2	(.002)	.11	.57	-

NOTES: (N) - Natural flow (unaffected by stream regulation)
(M) - Modified flow (period of record modified to include eff[illegible]ct of stream regulation)
(O) - Observed flow (observed value as modified by stream regu[illegible]on)

1 - All numbers in parentheses are in cfs per square mile.
2 - Storage in 1000 acre-feet per square mile required to sustain indicated flow in cfs per square mile. Example: Allegheny River at Redhouse requires 300 acre-feet per square mile to sustain a minimum flow of .2 cfs per square mile or to obtain a constant flow of 338 cfs requires 507,000 acre-feet of storage.

TABLE 22 (Cont'd)

STREAMFLOW CHARACTERISTICS FOR SELECTED GAGING STATIONS

Subbasin and Location	Period of Record	Drainage Area (Sq Mi)	Average Discharge (cfs)	Average Discharge (csm)	Floods - 1000 cfs, csm: Peak of Record 1000 cfs	csm	2 Year 1000 cfs	csm	50 Year 1000 cfs	csm	100 Year 1000 cfs	csm	Low Flows - cfs, csm: Minimum cfs	csm	7 Day-10 Year cfs	csm	Yield-Storage 1000 Acre-Feet Required per csm[2] .2	.6	.8
CUMBERLAND																			
Cumberland River							129.0	(12.1)	229.0	(21.4)	250.0	(23.4) (N)							
Carthage, Tenn	1922-59	10,700	17,020	1.59	210.0	(19.6)[1]	83.0	(7.8)	109.0	(10.2)	120.0	(11.2) (M)	336.0	(.034)	-	-	.05	-	.26
Cumberland River,							141.0	(8.5)	220.0	(13.3)	243.0	(14.7) (N)							
Dover, Tenn	1937-59	16,530	24,310	1.47	280.0	(16.9)	126.0	(7.6)	188.0	(11.4)	208.0	(12.6) (M)	414.0	(.025)	-	-	-	-	-
Roaring River,																			
Hilham, Tenn	1931-63	78.7	110	1.40	9.8	(124.5)	3.9	(49.6)	10.2	(129.8)	12.0	(152.6) (N)	1.9	(.024)	-	-	-	-	-
OHIO RIVER																			
Ohio River,							320.0	(9.0)	570.0	(16.0)	620.0	(17.4) (N)							
Parkersburg, W Va	1940-59	35,600	50,730	1.43	440.0	(12.4)	260.0	(7.3)	435.0	(12.2)	470.0	(13.2) (M)	2,290.0	(.064)	7,520.0	(.211)	-	-	-
Ohio River,							545.0	(5.0)	965.0	(9.0)	1,295.0	(12.1) (N)							
Evansville, Ind	1936-62	107,000	133,900	1.25	1,410.0	(13.2)	495.0	(4.6)	855.0	(8.0)	920.0	(8.6) (M)	-	-	16,200.0	(.151)	-	-	-

NOTES: (N) - Natural flow (unaffected by stream regulation)
(M) - Modified flow (period of record modified to include effect of stream regulation)
(0) - Observed flow (observed value as modified by stream regulation)

1 - All numbers in parentheses are in cfs per square mile.
2 - Storage in 1000 acre-feet per square mile required to sustain indicated flow in cfs per square mile. Example: Allegheny River at Redhouse requires 300 acre-feet per square mile to sustain a minimum flow of .2 cfs per square mile or to obtain a constant flow of 338 cfs requires 507,000 acre-feet of storage.

TABLE 23

PRINCIPAL GROUND WATER SUPPLIES
(Numerical ranges represent typical values and do not include unusually high or low values)

Subbasin Area	Aquifer Type	Yields of High Capacity Wells (gpm)	Well Depth (ft)	Depths to Water (ft)	Hardness (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Iron (mg/l)	Total Dissolved Solids (mg/l)	Temperature (°F.)
Allegheny	Unconsolidated	100-2000	12-260	0-30	36-280	1-350	1-90	0-8.5	57-600	48-54
	Bedrock	20-2000	14-810	0-100	10-330	1-160	1-160	0-19	22-580	48-54
Monongahela	Unconsolidated	100-300	50-130	15-35	120-1700	50-1500	20-350	1-120	300-3000	53-67
	Bedrock	20-300	80-500 400-1100(1)	0-150 50-500(1)	10-350	0-150	1-250	0.2-6.0	50-700	50-58
Upper Ohio	Unconsolidated	20-1500	60-140	10-50	130-400	50-200	5-60	0.1-3.0	200-650	51-57
	Bedrock	20-750	60-350	0-150	60-350	2-80	2-80	0.1-3.0	200-800	50-55
Muskingum & Hocking	Unconsolidated	75-2100	35-290	-	150-900	-	0-800	0-8.0	180-1000	51-52
	Bedrock	5-600	20-500	-	20-570	-	0-650	0.1-5.0	50-1000	52-58
Little Kanawha & Kanawha	Unconsolidated	10-1500	50-130	-	20-650	-	5-380	2-50	220-460	52-60
	Bedrock	5-5000	25-600	-	6-930	-	1.5-1000	0-38	42-1000	53-58
Scioto	Unconsolidated	10-1500	20-150	-	50-525	5-175	3-75	0.1-15	75-650	48-58
	Bedrock	5-250	75-750	-	50-700	50-125	4-200	0.05-15	75-1000	51-59
Guyandotte, Big Sandy & Little Sandy	Unconsolidated	25-500	60-80	30-40	70-210	5-100	10-50	0.1-3.0	150-500	-
	Bedrock	20-500	110-400	-	50-400	30-350	10-50	-	-	-
Great Miami & Little Miami	Unconsolidated	0-3000	40-200	5-100	300-550	30-120	5-30	0-4.0	300-650	52-56
	Bedrock	0-50	100-200	5-60	300-600	40-150	10-60	0.5-10	350-700	52-56
Licking & Kentucky	Unconsolidated	5-1000	60-160	-	250-350	20-70	5-20	0.01-0.2	300-450	53-58
	Bedrock	1-500	35-500	-	50-800	2-500	5-500	0.01-10	200-800	53-58
Wabash	Unconsolidated	100-1500	30-340	0-120	250-450	2-380	0-55	1-3	220-600	52-57(2)
	Bedrock	100-500	50-700	10-130	230-860	0-650	2-80	1-3	330-1450	52-58(2)
Lower Ohio	Unconsolidated	100-1500	40-180	5-50	90-600	5-200	5-30	0.2-3.5	170-900	-
	Bedrock	20-600	50-1000	-	50-450	5-250	5-75	0.1-5.0	200-2100	-
Cumberland	Unconsolidated	20-50	50-120	10-30	-	-	-	-	-	-
	Bedrock	20-100	60-300	10-100	40-400	5-200	2-100	0.2-6.0	200-500	55-65

NOTES: (1) Where Pottsville and Allegheny Formations are overlain by the Conemaugh Formation.
(2) Water from Devonian rocks in Illinois part of Basin at 600 to 700 feet depth, 59° to 66°F.

TABLE 24

POTENTIAL RESERVOIR SITES[1]

Subbasin and Reservoir	Drainage Area Controlled (Sq Mi)	Storage Capacity (1000 Ac Ft) Minimum	Other	Flood Control	Total[2]	Area of Pool (Acres) Minimum	Total
ALLEGHENY							
Clear Shade Creek	29	0.4	-	15.6	16.0	100	700
Cussewago Creek	91	2.6	16.6	24.5	43.7	200	2,000
Mill Creek	833	17.0	635.0	204.0	856.0	700	10,650
North Branch	28	7.0	-	15.0	22.0	400	1,050
Shanksville	32	8.0	-	17.0	25.0	200	4,650
Sugar Creek	98	4.5	-	26.5	31.0	500	1,200
Redbank Creek	460	3.0	-	139.0	142.0	225	3,600
MONONGAHELA							
Big Sandy Creek	97	3.0	-	84.0	87.0	300	2,130
Crellin	56	1.0	-	94.0	95.0	100	3,650
Elk Creek	84	2.0	45.0	82.0	129.0	200	4,400
Laurel Hill Creek	115	1.3	-	60.7	62.0	150	1,400
Middle Fork River	137	8.0	-	220.0	228.0	500	5,300
Rowlesburg	936	9.5	522.6	299.6	831.7	550	9,140
Stonewall Jackson	102	2.0	35.2	38.0	75.2	200	3,290
Wymer	44	2.0	40.0	73.0	115.0	200	1,920
BEAVER							
Eagle Creek	95	10.0	78.0	33.0	121.0	2,100	7,900
Grand River	1,002	1,802.0	-	405.0	2,207.0	64,200	71,100
MUSKINGUM							
Boggs Fork	15	1.0	-	4.0	5.0	160	360
Conser Run	15	0.9	-	4.2	5.1	158	363
Frazeysburg	62	10.0	-	52.0	62.0	970	3,440
Hugle Run	9	4.9	-	3.3	8.2	410	544
Middle Branch	27	2.1	-	7.2	9.3	400	1,260
Millersburg	381	0	-	77.0	77.0	-	-
Ogg	12	0.7	4.5	3.3	8.5	70	375
Skull Fork	46	2.5	-	12.5	15.0	450	1,000
Utica	114	6.8	47.2	28.0	82.0	1,040	4,820
Valley Run	25	1.4	5.8	7.9	15.1	190	1,028
LITTLE KANAWHA							
Burnsville	166	4.0	4.0	58.0	66.0	475	1,970
Leading Creek	146	6.8	-	55.6	62.4	600	2,280
N Fork Hughes River	90	5.0	-	25.0	30.0	500	1,450
West Fork	238	8.0	-	77.1	85.1	600	2,930
HOCKING							
Federal Creek	139	17.7	-	56.7	74.4	1,190	3,460
Logan	84	3.3	38.8	35.9	78.0	260	1,360
McLeish	31	4.4	-	9.6	14.0	400	820
Monday Creek	77	18.7	-	30.6	49.3	1,385	2,355
Sugar Grove	231	8.0	-	42.4	50.4	870	3,820
KANAWHA							
Anthony Lake	143	3.0	260.0	38.0	301.0	200	4,830
Big Bend	1,631	1.0	-	107.5	108.5	150	3,100
Big Reed Island Creek	259	5.0	344.7	41.4	391.1	180	4,860
Big Sandy Creek	94	3.3	30.0	20.0	53.3	100	1,690
Birch	142	3.7	55.5	46.2	105.4	200	1,420
Bluestone River	232	9.0	271.0	40.0	320.0	200	1,650
Buffalo Creek	114	5.6	37.0	24.3	66.9	150	1,130
Clear Fork	39	2.1	-	18.8	20.9	100	380
Greenbrier	350	10.0	455.0	96.0	561.0	400	5,420
Indian Creek	151	4.0	60.0	23.0	87.0	300	2,050
Kimberling Creek	90	2.0	103.0	15.0	120.0	200	2,850
Little River (Lower)[3]	339	4.0	80.0	23.0	107.0	250	2,330
Little River (Upper)	198	5.3	112.4	31.7	149.4	320	3,280
Marsh Fork	44	1.0	9.0	10.0	20.0	100	1,000
Meadow River	322	8.0	92.0	40.0	140.0	250	2,800
Moores Ferry	1,130	60.0	-	361.0	421.0	400	7,500
New River	630	15.0	465.0	100.0	580.0	600	9,300
Poca	245	8.0	-	186.0	194.0	300	6,250
Reed Creek	258	6.9	66.3	41.3	114.5	350	2,920
S Fork New River	200	5.0	138.0	32.0	175.0	150	2,700
Walker Creek	303	8.0	254.0	48.0	310.0	350	7,200
GUYANDOTTE							
Barkers Creek	16	0.8	2.2	5.0	8.0	41	133
Clear Fork	22	1.2	1.9	7.0	10.1	80	276
Indian Creek	34	1.8	3.0	10.9	15.7	165	495
Laurel Fork	47	2.5	3.8	15.0	21.3	150	525
Little Huff Creek	20	1.0	1.5	6.4	8.9	77	240
Marsh Fork	4	0.6	-	1.8	2.4	110	225
Mud River	270	6.2	-	84.1	90.3	644	4,270
Pinnacle Creek	56	3.0	4.4	17.9	25.3	150	510
Rockcastle Creek	3	0.6	0.1	1.4	2.1	190	285
Tommy Creek	13	0.7	2.3	4.4	7.4	42	154
BIG SANDY							
Haysi	88	2.0	23.5	42.5	68.0	100	1,120
Knox Creek (Lower)[3]	99	3.0	6.7	50.3	60.0	113	1,000
Knox Creek (Upper)	14	0.7	6.7	11.3	18.7	34	299
Paintsville	92	4.5	22.9	49.0	76.4	240	1,890
Panther Creek	24	1.7	5.1	10.1	16.9	60	288
Yatesville	208	12.1	4.5	83.2	99.8	950	4,200

TABLE 24 (Cont'd)

POTENTIAL RESERVOIR SITES(1)

Subbasin and Reservoir	Drainage Area Controlled (Sq Mi)	Storage Capacity (1000 Ac Ft) Minimum	Other	Flood Control	Total(2)	Area of Pool (Acres) Minimum	Total
SCIOTO							
Alum Creek	123	2.4	74.1	47.5	124.0	380	4,600
Bellepoint	736	3.2	-	85.0	88.2	500	11,170
Mill Creek	181	4.0	-	88.5	92.5	420	6,200
Roundhead	34	0.9	-	11.0	11.9	190	1,020
Upper Darby	239	1.0	24.5	7.0	32.5	100	2,820
LITTLE MIAMI							
Cowan Creek	51	2.0	-	12.0	14.0	550	650
Morrow	685	36.0	-	208.0	244.0	1,800	7,000
Washington Mills	308	16.0	-	45.0	61.0	1,000	2,720
Todd Fork	245	13.0	-	82.0	95.0	1,800	7,790
GREAT MIAMI							
Blue Creek	26	0.2	-	28.8	29.0	100	492
Dry Fork	45	2.4	-	34.6	37.0	600	8,200
Duck Creek	25	1.3	-	16.7	18.0	100	640
Oldenburg	80	8.6	-	54.4	63.0	500	1,400
Pipe Creek	66	2.6	-	65.7	68.3	100	1,465
Williams Creek	28	1.5	1.6	25.4	28.5	400	10,150
LICKING							
Falmouth	1,505	78.4	171.3	648.6	898.3	4,500	25,700
Hinkston Creek	174	9.0	21.4	97.6	128.0	1,000	6,000
Royalton	76	1.4	13.0	32.9	47.3	400	1,770
KENTUCKY							
Cutskin Creek	84	4.5	15.5	49.0	69.0	150	1,400
Ford	2,503	130.0	200.0	510.0	840.0	4,000	33,400
Greasy Creek	51	2.7	11.4	16.1	30.2	80	570
Kingdom Come	131	7.0	17.0	49.0	73.0	500	1,680
Leatherwood Creek	49	2.6	-	32.4	35.0	50	770
Line Fork	64	3.4	-	58.6	62.0	150	1,120
Little Goose Creek	38	2.0	7.6	20.4	30.0	100	920
Red Bird River	115	6.0	29.0	55.0	90.0	200	1,930
Station Camp Creek	95	5.0	255.0	30.0	290.0	200	3,300
Troublesome Creek	201	11.0	29.8	71.2	112.0	250	2,470
Walkers Creek	1,260	3.5	30.0	147.0	180.5	100	5,630
SALT							
Camp Ground	438	24.3	80.3	344.0	448.6	150	11,950
Floyds Fork	42	5.8	63.7	70.0	139.5	100	3,380
Howardstown	384	22.7	39.6	307.0	369.3	150	10,500
Taylorsville	354	17.2	103.1	278.8	399.1	100	7,885
GREEN							
Drakes Creek	500	30.0	7.0	270.0	307.0	400	8,200
WABASH							
Azalia	250	13.3	-	138.9	152.2	1,700	6,530
Bean Blossom	167	9.0	-	105.0	114.0	2,050	7,000
Big Blue	269	10.6	34.4	75.1	120.1	1,330	5,970
Big Muddy	140	4.5	-	41.5	46.0	700	3,700
Big Pine	331	9.0	-	201.5	210.5	687	4,710
Big Walnut	197	9.7	153.0	160.7	323.4	1,024	7,984
Brouilletts Creek	300	16.0	-	167.0	183.0	1,550	5,790
Clifty Creek	140	7.6	-	48.6	56.2	548	2,390
Coal Creek	244	13.6	-	156.6	170.2	1,020	52,160
Crawfordsville	423	22.6	-	138.6	161.2	1,400	5,040
Danville	970	52.0	-	361.0	413.0	2,900	11,750
Denver	680	36.3	-	226.7	263.0	2,675	13,550
Deputy	294	16.0	28.0	103.0	147.0	1,100	4,320
Downeyville	276	15.1	75.5	71.3	161.9	900	6,070
Fortville	172	9.0	32.0	35.0	76.0	1,100	3,600
Fox River	84	4.5	-	50.0	54.5	700	4,100
Helm	210	12.0	47.7	112.1	171.8	2,040	9,930
Lafayette	787	19.2	-	313.3	332.5	1,320	9,470
Lincoln	915	55.0	6.3	477.0	538.3	4,310	21,250
Louisville	661	38.8	44.0	148.0	230.8	5,000	13,500
Martinsville	2,430	83.0	-	550.0	633.0	8,500	28,700
Maltersville	56	1.7	26.8	44.8	73.3	535	3,550
N Fork Embarras River	140	7.5	-	134.5	142.0	1,000	6,400
Parker City	175	8.0	82.3	42.7	133.0	900	10,150
Patoka	168	13.2	167.5	144.1	324.8	2,010	11,760
Perkinsville	542	25.0	10.0	34.0	69.0	2,600	5,200
Shoals	4,947	204.0	-	1,066.0	1,270.0	18,000	67,000
Tippecanoe	525	28.0	-	214.0	242.0	4,500	24,320
Vernon Fork	226	12.1	24.0	76.7	112.8	1,280	3,700
CUMBERLAND							
Clover Fork	29	3.5	-	7.6	11.1	117	218
Devils Jumps	957	2,230.0	1,650.0	256.0	4,136.0	18,260	36,990
Kettle Isle	46	4.8	-	14.9	19.7	285	NA
Letcher-Harlan	52	3.0	-	14.3	17.3	197	593
Little Clear Creek	14	4.0	0.9	4.6	9.5	204	NA
Martins Fork	56	3.7	-	18.1	21.8	270	675
Presley House Branch	14	1.0	-	3.9	4.9	40	NA
Rossview	955	20.0	-	352.0	372.0	1,395	9,400
Three Isles	854	212.0	152.0	351.0	715.0	7,190	14,560

TABLE 24 (Cont'd)

POTENTIAL RESERVOIR SITES(1)

Subbasin and Reservoir	Drainage Area Controlled (Sq Mi)	Storage Capacity (1000 Ac Ft) Minimum	Other	Flood Control	Total(2)	Area of Pool (Acres) Minimum	Total
TWELVEPOLE CREEK, W VA							
Cabwaylingo	40	2.1	-	19.3	21.4	160	660
WHITEOAK CREEK, OHIO							
Whiteoak	214	22.0	6.0	71.5	99.5	670	2,200
MIDDLE ISLAND CREEK, W VA							
Delong	554	5.0	-	190.0	195.0	NA	NA
Meathouse Fork	50	3.0	-	27.0	30.0	NA	NA
KINNICONICK CREEK, W VA							
Kinniconick Creek	253	14.6	5.9	85.8	106.3	980	2,840
TYGARTS CREEK, KY							
Kehoe	127	4.8	8.6	65.6	79.0	400	1,980
SALINE RIVER							
Bear Creek	48	5.0	-	55.0	60.0	NA	NA
Bushy Creek	22	6.0	-	24.0	30.0	NA	NA
Stone Fort	30	5.0	-	30.0	35.0	NA	NA
MILL CREEK, W VA							
Ripley	130	5.0	-	55.0	60.0	NA	NA
OHIO BRUSH CREEK							
Buzzardsroost	402	2.0	-	171.0	173.0	150	4,260
CACHE RIVER							
Dam #2, Cache River	40	1.0	-	12.0	13.0	NA	NA
Dam #3, Cache River	38	0.4	-	4.6	5.0	NA	NA
Dam #4, Cache River	8	0.5	-	1.5	2.0	NA	NA
Dam #5, Cache River	10	1.0	-	11.0	12.0	NA	NA
Dam #6, Cache River	6	0.4	-	1.1	1.5	NA	NA
Dam #7, Cache River	2	0.5	-	1.0	1.5	NA	NA
Dam #8, Cache River	2	0.4	-	0.6	1.0	NA	NA

NOTES: (1) Sites which are considered to have economic potential for development by 2020. Additional storage sites are available in each subbasin. All data subject to change upon detailed studies.

(2) Storage given is that amount considered economically feasible. Total storage capability may be greater.

(3) Alternate to upper site.

TABLE 24A

SUMMARY OF POTENTIAL LOCAL PROTECTION PROJECTS

	Major Local Protection Projects Number	Length in Miles of Levees & Walls	Channel Improvements	Number of Small Local Protection Projects
Allegheny	4	1.4	4.3	2
Monongahela	3	(1)	5.1	9
Beaver	2	(1)	(1)	None
Muskingum	1	(1)	(1)	2
Kanawha, Little Kanawha	None	0	0	None
Guyandotte, Big Sandy, Little Sandy	6	0.8	20.2	7
Scioto	6	10.3	0	1
Great Miami, Little Miami	None	0	0	1
Licking, Kentucky, Salt	2	1.0	(1)	4
Green	None	0	0	2
Wabash	36	324.9	32.0	4
Cumberland	1	0	1.2	16
Ohio River and Minor Tributaries	34	60.2	25.7	1
Totals	95	398.6	88.5	49

NOTES: (1) Total project dimensions not defined at this time.

TABLE 25

POTENTIALLY FEASIBLE WATERSHED PROJECTS

Watersheds (1)	Area in Watershed (Sq Mi)	Number of Structures	Drainage Area Controlled (Sq Mi)	Storage Capacity: Sediment (Ac Ft)	Storage Capacity: Floodwater (Ac Ft)	Storage Capacity: Other Uses (Ac Ft)	Total Capacity (Ac Ft)	Water Surface Area (Acres)	Channel Improvement (Miles)
ALLEGHENY									
N. Y.									
1a2	139	9	45	724	8,926	6,365	16,015	522	16
1a5	63	1	39	547	6,745	782	8,074	770	-
Pa.									
1-1	228	7	52	753	9,281	11,384	21,418	531	-
1-3	9	1	7	99	1,226	1,294	2,619	78	-
1-9	334	9	100	1,553	19,148	39,566	60,267	2,726	-
1-12A	479	7	100	1,355	16,711	18,164	36,230	1,012	-
1-13A	174	6	72	824	10,166	12,659	23,649	582	-
1b-16A	62	3	26	338	4,169	2,523	7,030	385	-
1c-20,20A(2)	356	5	26	341	4,204	19,463	24,008	725	-
1-25,26	328	13	98	2,392	29,496	74,814	106,702	2,951	-
1-28	14	2	6	81	999	2,800	3,880	90	-
1d1-31,31(2)	413	8	77	1,097	13,530	50,088	64,715	1,985	-
1d1-32,32A	468	13	85	1,212	14,951	100,965	117,128	4,145	-
1d-35,35A	295	3	21	298	3,673	2,492	6,463	258	-
N. Y.									
1a4	202	13	92	2,261	28,923	19,344	50,528	1,566	-
1-1	137	10	34	539	6,648	7,431	14,618	333	-
1-4	45	2	5	86	1,064	967	2,117	62	3
MONONGAHELA									
Pa.									
*2c-38,38A	464	25	221	4,995	43,006	12,312	60,313	2,584	-
2c-40	115	7	53	1,069	9,114	1,083	11,266	587	3
2c-41A	36	1	18	352	3,001	1,881	5,234	201	-
W. Va.									
2-2	32	3	9	183	1,563	4,061	5,807	161	-
2-4	104	4	5	102	872	2,264	3,238	123	-
2-6	24	3	10	189	1,619	4,155	5,963	162	-
2-7	41	15	18	411	3,508	5,488	9,407	448	-
2-9	72	13	38	782	6,666	16,258	23,706	858	2
2a-1	85	4	7	146	1,251	3,242	4,639	147	-
2a-2	100	12	52	1,020	8,698	22,520	32,238	620	-
2a-3	88	9	23	445	3,800	8,597	12,842	270	-
2a-12	148	9	40	779	6,643	17,287	24,709	645	-
2a-19	49	2	13	264	2,250	5,858	8,372	375	-
2a1-1	85	3	2	50	426	1,106	1,582	55	4
2a1-4	124	13	39	758	6,461	16,784	24,003	1,174	-
2a1-11	41	13	23	452	3,855	10,031	14,338	531	-
2a1-12	130	8	33	648	5,526	14,367	20,541	868	1
2b-4	158	4	18	355	3,030	7,840	11,225	188	-
BEAVER									
Ohio									
3a-6	17	-	-	-	-	-	-	-	2
3a1-1	174	2	9	132	1,349	5,460	6,941	328	6
Pa.									
3b-54,54A	418	18	129	2,100	21,449	21,071	44,620	1,480	-
3b-55	56	2	23	409	4,182	2,749	7,340	499	-
3a1-56	240	10	92	1,609	16,450	15,516	33,575	2,125	-
MUSKINGUM									
Ohio									
4-4	231	18	103	2,727	14,318	68,089	85,134	3,000	61
4-5	146	16	68	1,808	9,489	98,417	109,714	3,247	15
4-3	301	25	97	2,555	13,412	142,579	158,546	4,665	71
4-6	32	3	14	356	1,869	33,290	35,515	880	7
4-2	234	21	50	1,329	6,979	81,608	89,916	2,535	71
4a-1	23	3	7	194	1,017	21,695	22,906	493	11
4a-7	22	4	4	97	511	14,424	15,032	438	10
4a-8	84	5	22	584	3,064	45,314	48,962	1,251	21
4a-5	187	6	23	605	3,177	2,243	6,025	610	54
4a-6	294	22	66	1,731	9,087	125,558	136,376	5,200	38
4a-2	42	2	13	329	1,725	36	2,090	185	18
4a-4	32	-	-	-	-	-	-	-	4
4a-3	165	5	22	586	3,075	5,615	9,276	593	32
4-1	396	27	181	4,425	25,478	80,670	110,573	3,599	50
4b-3	482	32	138	3,657	19,199	125,509	148,365	5,287	84
4b-2	190	4	24	630	3,310	21,107	25,047	884	31
4b-1	295	10	58	1,528	8,022	13,353	22,903	1,147	22
4c-1	44	4	9	228	1,194	13,717	15,139	485	8
4c-3	62	3	12	307	1,612	28,175	30,094	822	24
4d-2	184	12	42	1,103	5,790	8,475	15,368	830	39
4d-1	343	11	103	2,714	14,247	23,893	40,854	1,929	91
4c-4	50	3	19	559	2,936	5,503	8,998	101	9
4c-5	72	5	24	724	3,803	43,706	48,233	1,010	10
4c-2	92	9	24	624	3,276	61,554	65,454	1,299	69

* Watershed projects 2C-38 and 38A extend into Maryland.

TABLE 25 (Cont'd)

POTENTIALLY FEASIBLE WATERSHED PROJECTS

Watersheds(1)	Area in Watershed (Sq Mi)	Number of Structures	Drainage Area Controlled (Sq Mi)	Storage Capacity Sediment (Ac Ft)	Storage Capacity Floodwater (Ac Ft)	Storage Capacity Other Uses (Ac Ft)	Total Capacity (Ac Ft)	Water Surface Area (Acres)	Channel Improvement (Miles)
LITTLE KANAWHA									
W. Va.									
5-3	31	6	15	360	2,420	4,529	7,309	261	-
5-15	43	29	26	740	4,970	7,935	13,645	757	-
HOCKING									
Ohio									
6-3	145	5	39	826	3,542	25,879	30,247	796	50
6-4	60	6	19	572	2,450	4,486	7,508	304	10
6-8	91	13	27	851	3,646	23,245	27,742	992	25
6-10	17	3	3	101	432	3,046	3,579	123	10
KANAWHA									
W. Va.									
7-9	11	1	1	20	170	209	399	20	-
7-12	95	7	28	734	6,262	7,674	14,670	519	3
7-13,15	120	7	86	2,261	19,294	23,645	45,200	1,365	-
7-16	5	4	3	72	615	754	1,441	53	-
7-17	46	11	23	604	5,150	6,310	12,064	363	-
7-19	3	1	1	34	292	358	684	14	-
7-22	24	5	11	232	1,979	3,402	5,613	122	-
7-26	73	8	32	831	7,087	8,687	16,605	231	-
7-28	25	3	12	458	3,904	2,223	6,585	102	-
7a-1	11	3	6	160	1,361	1,665	3,186	62	-
7a-2	49	2	8	194	1,652	591	2,437	93	1
7a-5	137	8	49	1,293	11,029	6,719	19,041	577	5
7a-6	28	1	3	80	679	833	1,592	31	1
7a-7	54	1	11	292	2,492	3,055	5,839	178	4
7a-18	88	3	16	430	3,667	4,500	8,597	265	-
7a1-3	123	1	1	15	124	150	289	11	-
7a1-5	92	11	34	1,205	10,282	11,753	23,240	545	-
7b-6	203	10	118	3,041	25,947	32,615	61,603	338	12
7b-7	104	4	57	1,506	12,847	15,740	30,093	715	1
7b-10	39	1	8	220	1,880	2,304	4,404	308	6
7b-13	164	3	88	2,308	19,698	24,918	46,924	617	-
7c-2	35	1	22	67	576	604	1,247	49	-
7c-5	79	7	37	1,043	8,893	9,646	19,582	434	-
7c-9	19	3	8	212	1,805	2,209	4,226	136	-
7c-10	50	2	19	499	4,258	5,218	9,975	272	-
7c-14	143	6	56	1,462	12,469	15,282	29,213	515	-
7d-6	133	13	78	2,044	17,401	21,339	40,784	794	-
7d-7	105	9	55	1,442	12,300	15,071	28,813	523	-
7d-9	65	2	42	1,106	9,434	11,562	22,102	273	-
Va.									
7a-1	55	5	24	614	5,234	-	5,848	241	2
7a-4	40	4	22	574	4,894	6,064	11,532	363	-
7a-9	94	8	36	948	8,085	9,867	18,900	869	-
GUYANDOTTE									
W. Va.									
8-4	52	8	26	489	4,284	9,863	14,636	620	1
8-5	84	6	48	892	7,847	18,194	26,933	747	3
8-10	27	-	-	-	-	-	-	-	13
8-18	101	4	18	341	2,988	6,872	10,201	262	-
8-20	106	2	68	1,602	14,037	22,299	37,938	668	-
8-21	21	2	15	357	3,130	4,834	8,321	143	-
8-24	134	5	15	379	3,324	4,672	8,375	186	2
BIG SANDY									
Ky.									
9-1	265	16	140	3,556	26,251	63,633	93,440	3,203	16
9a-4	12	1	5	122	903	812	1,837	58	-
9a-8	171	8	60	1,508	11,129	11,558	24,195	776	-
9a-9	53	6	28	833	6,147	5,990	12,970	381	-
9a-11	11	1	3	95	705	591	1,391	61	2
9a-13	17	2	7	143	1,057	784	1,984	79	-
9a-14	64	4	24	636	4,694	8,988	14,318	486	-
9a-16	17	2	9	243	1,796	5,061	7,100	243	-
9a-17	169	5	91	2,219	16,379	25,905	44,503	1,480	-
9a-19	16	1	5	125	925	794	1,844	77	-
9b-1	34	2	15	400	2,950	2,854	6,204	153	-
9b-3	21	2	9	230	1,700	1,562	3,492	96	-
9b-5	59	3	31	824	6,060	8,600	15,484	424	-
9b-6	83	4	33	1,241	9,158	13,128	23,527	785	-
9b-7	121	4	55	1,388	10,241	20,922	32,551	1,158	10
W. Va.									
9-1	95	9	5	111	815	879	1,805	132	11
9b-4	17	3	3	83	610	527	1,220	48	-
9b-11	72	7	15	345	2,549	3,547	6,441	221	-

TABLE 25 (Cont'd)

POTENTIALLY FEASIBLE WATERSHED PROJECTS

Watersheds [1]	Area in Watershed (Sq Mi)	Number of Structures	Drainage Area Controlled (Sq Mi)	Storage Capacity: Sediment (Ac Ft)	Storage Capacity: Floodwater (Ac Ft)	Storage Capacity: Other Uses (Ac Ft)	Total Capacity (Ac Ft)	Water Surface Area (Acres)	Channel Improvement (Miles)
BIG SANDY (Cont'd)									
Va.									
9-1	62	1	17	383	2,827	1,781	4,991	162	2
9-4	104	1	27	515	3,804	-	4,319	98	-
SCIOTO									
Ohio									
10-4	15	-	-	-	-	-	-	-	9
10-6	145	3	24	649	3,355	9,039	13,043	410	24
10-12	16	-	-	-	-	-	-	-	11
10-13	23	-	-	-	-	-	-	-	7
10-16	53	2	6	155	799	1,123	2,077	134	-
10-21	280	8	50	1,328	6,872	14,664	22,864	1,170	64
10-22.1	45	-	-	-	-	-	-	-	14
10-22.2	201	10	37	978	5,058	3,355	9,391	738	51
10-22.3,4	312	8	41	1,092	5,655	3,345	10,092	916	46
10-24.2	475	8	51	1,350	6,987	5,168	13,505	946	14
10-30	17	-	-	-	-	-	-	-	7
10-31	111	2	9	248	1,283	-	1,531	207	36
10-32	391	6	47	1,244	6,441	5,650	13,335	1,010	100
10a-3	16	-	-	-	-	-	-	-	8
10a-4	14	1	5	137	709	8,387	9,233	232	7
10a-5	40	2	4	119	614	1,495	2,228	109	-
10a-6	145	5	27	720	3,723	24,697	29,140	1,047	-
10a-7	277	7	38	1,028	5,323	19,009	25,360	1,114	-
10-10	306	12	64	1,712	8,856	55,478	66,046	1,338	57
10-10.1	247	11	46	1,240	6,415	51,975	59,630	1,236	42
LITTLE MIAMI									
Ohio									
11-5	58	7	24	602	3,417	4,829	8,848	424	-
11-8	261	10	92	2,243	12,801	25,161	40,205	2,050	45
11-9,9.1	239	10	48	1,179	6,686	14,528	22,393	1,191	61
11-12	34	4	19	480	2,726	2,862	6,068	245	5
11-11	47	2	3	76	431	1,005	1,512	78	17
11-10,12	214	3	17	430	2,439	4,276	7,145	284	72
GREAT MIAMI									
Ohio									
13-3	16	1	2	48	260	935	1,243	47	8
13-4	106	17	39	1,007	5,464	4,564	11,035	655	31
13-5	322	11	58	1,499	8,134	8,698	18,331	1,158	81
13-8	48	1	6	164	889	394	1,447	59	12
13-9	315	9	74	1,926	10,452	4,397	16,775	1,099	48
13-11,13	54	-	-	-	-	-	-	-	12
13-14.2-14.25	141	4	8	208	1,127	2,139	3,474	272	35
13-14.3,14.4	309	15	35	915	4,964	16,345	22,224	1,237	69
13-15.5	201	3	20	529	2,868	648	4,045	554	32
13-15.6	217	6	31	801	4,349	2,120	7,270	936	57
13-21	56	2	5	127	687	153	967	123	13
13-24	63	1	10	309	1,406	-	1,715	118	21
13-25	332	3	12	300	1,630	-	1,930	193	49
Ind.									
13a-1,2	529	16	285	7,065	38,758	37,322	83,145	3,149	-
13a-8	386	16	83	2,174	11,800	11,710	25,684	923	-
13a-4	119	11	34	1,128	6,122	19,343	26,593	1,303	39
LICKING									
Ky.									
12-1	147	7	76	2,175	13,475	59,111	74,761	2,503	-
12-2	48	4	30	748	4,632	6,477	11,857	466	3
12-7	51	1	5	-	-	1,349	1,349	71	6
12-12	39	3	13	254	1,576	8,453	10,283	414	12
12-14	187	17	87	2,484	15,398	27,493	45,375	1,639	20
12-15	50	2	42	1,332	8,248	9,784	19,364	487	-
12-16	79	5	25	795	4,923	825	6,543	319	7
12-21	120	4	80	2,435	15,085	47,853	65,373	2,104	-
12a-1	282	22	144	3,027	18,753	37,859	59,639	3,737	-
KENTUCKY									
Ky.									
14-6	70	5	30	1,115	8,889	3,036	13,040	550	18
14-8	58	3	32	925	7,375	324	8,624	210	7
14-12	111	1	73	1,360	10,840	-	12,200	259	-
14-13	74	2	30	891	7,108	3,289	11,288	295	-
14-14	217	15	136	1,932	15,407	56,112	73,451	1,618	20
14-20	119	2	84	1,749	13,950	681	16,380	509	-
14-21	85	3	60	1,432	11,417	8,646	21,495	587	-
14-22	25	3	12	283	1,901	5,011	7,195	274	-
14-23	96	2	74	1,905	15,193	5,752	22,850	985	-

TABLE 25 (Cont'd)

POTENTIALLY FEASIBLE WATERSHED PROJECTS

Watersheds (1)	Area in Watershed (Sq Mi)	Number of Structures	Drainage Area Controlled (Sq Mi)	Storage Capacity: Sediment (Ac Ft)	Storage Capacity: Floodwater (Ac Ft)	Storage Capacity: Other Uses (Ac Ft)	Total Capacity (Ac Ft)	Water Surface Area (Acres)	Channel Improvement (Miles)
KENTUCKY (Cont'd)									
Ky.									
14-27	99	1	63	1,224	9,774	-	11,000	419	-
14-37	110	3	57	1,677	13,372	4,524	19,573	629	-
14-33	107	5	62	1,794	14,305	8,943	25,042	1,140	-
14-34	22	1	11	329	2,621	1,250	4,200	123	2
14-36	82	3	47	1,347	11,032	101	12,480	375	-
14-39	36	3	24	713	5,686	1,551	7,950	216	6
14a-8	246	13	149	5,194	41,426	8,487	55,107	1,180	4
14a-9	42	1	28	836	6,664	900	8,400	226	5
14a-10	202	1	105	3,013	24,034	953	28,000	606	-
14b-2	247	15	141	4,409	35,162	23,714	63,285	1,740	-
14b-3	30	4	13	437	3,487	5,507	9,431	214	-
14b-5	18	3	8	234	1,866	2,776	4,876	136	-
14-30	64	1	18	201	1,601	743	2,545	102	-
SALT									
Ky.									
15-6	62	1	33	935	7,365	2,576	10,876	511	-
15-7	75	1	53	1,160	9,140	3,081	13,381	699	-
15-12	55	3	15	409	3,222	11,396	15,027	682	-
15-14	163	9	72	2,033	16,059	21,075	39,167	1,826	-
15-16	36	5	10	279	2,196	3,308	5,783	242	-
15a-1	239	12	145	3,294	25,957	14,875	44,126	1,767	-
15a-2	24	2	17	726	5,724	23,043	29,493	1,096	-
15a-6	84	5	40	1,165	9,185	1,606	11,956	579	-
15a-7	60	5	33	997	7,854	4,410	13,261	615	-
15a-8	50	3	31	1,002	7,898	5,643	14,543	599	6
GREEN									
Ky.									
16-1	363	8	109	2,950	16,940	18,510	38,400	2,157	-
16-2	83	5	30	918	5,272	9,485	15,675	692	-
16-4	289	5	162	4,597	26,403	34,268	65,268	1,722	-
16-5	10	1	6	178	1,022	2,075	3,275	98	-
16-6	135	6	71	2,678	15,382	309	18,369	733	-
16-7	83	3	21	489	2,811	7,541	10,841	439	-
16-8	256	13	81	1,909	10,963	59,233	72,105	2,645	-
16-9	30	1	20	464	2,666	1,743	4,873	231	-
16-10	52	4	34	792	4,548	11,091	16,431	816	9
16-11	52	2	19	438	2,512	6,182	9,132	515	6
16-12	20	2	7	176	1,009	12,426	13,611	500	7
16-15	93	1	36	845	4,855	2,991	8,691	374	7
16-18	159	6	44	1,142	6,558	25,252	32,952	1,145	16
16-20	32	3	7	177	1,013	6,506	7,696	280	-
16-22	54	10	33	787	4,518	27,302	32,607	1,336	10
16-28	126	5	34	1,025	5,885	8,412	15,322	937	9
16-29	37	3	19	455	2,610	12,935	16,000	1,142	5
16-31	28	2	6	151	869	3,748	4,768	419	8
16-32	27	4	12	313	1,797	9,007	11,117	892	6
16-34	121	16	41	961	5,521	41,616	48,098	2,786	25
16-36	103	11	25	606	3,483	19,125	23,214	1,347	27
16-37	57	4	20	468	2,690	20,259	23,417	1,385	10
16-38	10	1	6	147	843	4,449	5,439	489	1
16-39	26	1	4	104	596	2,319	3,019	310	5
16-40	25	3	10	236	1,352	5,120	6,708	519	8
16a-2	86	7	28	663	3,809	6,937	11,409	555	-
Tenn.									
16a-3	118	4	53	2,397	13,763	99,955	116,115	2,839	12
Ky.									
16a-6	14	2	8	197	1,133	3,382	4,712	152	-
16a-8	74	5	35	822	4,723	13,759	19,304	721	-
16a-9	139	5	54	1,299	7,461	2,485	11,245	644	-
16a-12	20	2	10	228	1,307	6,970	8,505	300	2
16a-13	79	3	44	1,309	5,971	9,215	16,495	582	-
16a-15	17	1	5	128	732	196	1,056	56	-
16a-16	47	2	27	659	3,791	3,847	8,297	361	-
16a-18	135	10	59	1,515	8,639	14,561	24,715	960	24
16a-20	48	3	19	451	2,589	9,440	12,480	552	-
16b-2	58	4	30	691	3,971	7,593	12,255	485	7
16b-4	8	1	5	108	622	1,772	2,502	96	-
16b-6	65	7	28	644	3,701	6,401	10,746	655	15
16b-9	73	6	23	543	3,117	14,274	17,934	1,026	15
16c-3	67	4	8	192	1,103	7,094	8,389	469	28
16c-4	32	1	5	117	673	1,325	2,115	162	11
16c-5	35	5	13	311	1,787	7,563	9,661	678	8
16c-6	37	-	-	-	-	-	-	-	10
16-33	8	-	-	-	-	-	-	-	5
WABASH-EMBARRAS									
17g-1;EM-1	28	1	3	114	923	2,025	3,062	121	-
17g-2;EM-2	35	-	-	-	-	-	-	-	13
17g-3;EM-3	55	5	11	398	2,224	8,489	11,111	412	-
17g-4;EM-4	11	-	-	-	-	-	-	-	4

TABLE 25 (Cont'd)

POTENTIALLY FEASIBLE WATERSHED PROJECTS

Watersheds (1)	Area in Watershed (Sq Mi)	Number of Structures	Drainage Area Controlled (Sq Mi)	Storage Capacity Sediment (Ac Ft)	Storage Capacity Floodwater (Ac Ft)	Storage Capacity Other Uses (Ac Ft)	Total Capacity (Ac Ft)	Water Surface Area (Acres)	Channel Improvement (Miles)
WABASH-EMBARRAS (Cont'd)									
17g-5;EM-5	101	2	11	460	3,729	4,304	8,493	176	-
17g-7;EM-7	38	8	17	598	4,841	6,764	12,203	357	-
17g-8;EM-8	101	7	26	959	7,763	4,460	13,182	127	-
17g-11;EM-11	357	16	172	5,756	46,617	44,827	97,200	2,890	-
17g-12;EM-12	78	7	29	1,067	8,640	2,894	12,601	186	-
17g-20;EM-20	59	4	30	1,182	9,573	9,823	20,578	326	-
17g-21;EM-21	216	18	77	3,537	28,654	26,166	58,357	1,187	-
17g-23;EM-23	57	5	42	1,586	12,846	11,571	26,003	271	-
17g-33;EM-33	146	-	-	-	-	-	-	-	17
17g-31;EM-31	18	-	-	-	-	-	-	-	3
17g-32;EM-32	41	-	-	-	-	-	-	-	17
17g-41,36;EM-36	37	-	-	-	-	-	-	-	19
17g-42,37;EM-37	9	-	-	-	-	-	-	-	5
WABASH-SALAMONIE									
17-15,8;S-8	46	-	-	-	-	-	-	-	14
17-14,13;S-13	15	-	-	-	-	-	-	-	6
17-15,10;S-10	9	-	-	-	-	-	-	-	8
17-15,12;S-12	31	-	-	-	-	-	-	-	12
17-12,15;S-15	273	-	-	-	-	-	-	-	25
WABASH-WHITE-MAIN STEM									
17h-4,4;WM-4	34	9	16	463	3,749	12,521	16,733	781	-
17h-3,5;WM-5	17	1	6	168	1,361	3,813	5,342	161	-
17h-2,6;WM-6	14	3	5	137	1,112	129	1,378	122	6
WABASH-WILDCAT									
17d-2,4;W-4	242	1	17	413	3,347	1,756	5,516	36	-
17d-3,3;W-3	118	-	-	-	-	-	-	-	13
WABASH-VERMILION									
17e-3;V-3	16	1	13	316	2,556	1,055	3,927	79	-
17e-7;V-7	125	-	-	-	-	-	-	-	36
17e-11;V-11	72	1	15	425	3,455	2,335	6,215	50	10
17e-12;V-12	390	2	19	416	3,366	848	4,630	70	35
17e-21;V-21	308	-	-	-	-	-	-	-	43
WABASH-MISSISSENEWA									
17a-2,13;MI-13	8	-	-	-	-	-	-	-	5
17a-2,14;MI-14	75	-	-	-	-	-	-	-	22
17a-1,17;MI-17	263	-	-	-	-	-	-	-	134
17a-2,8;MI-8	58	-	-	-	-	-	-	-	13
WABASH-UPPER WABASH									
17-8,5;U-5	287	6	68	1,278	10,349	2,051	13,678	856	3
17-6,6;U-6	92	-	-	-	-	-	-	-	28
17-3,10;U-10	27	-	-	-	-	-	-	-	11
17-3,11;U-11	11	-	-	-	-	-	-	-	5
17-3,14;U-14	108	1	1	24	196	1,535	1,755	82	-
17-3,16;U-16	6	-	-	-	-	-	-	-	3
17-2,20;U-20	260	-	-	-	-	-	-	-	12
WABASH-TIPPECANOE									
17c-21,9;T-9	156	-	-	-	-	-	-	-	45
17c-19,10;T-10	11	-	-	-	-	-	-	-	10
17c-18,16;T-16	7	-	-	-	-	-	-	-	4
17c-11,25;T-25	14	-	-	-	-	-	-	-	6
17c-8,34;T-34	3	-	-	-	-	-	-	-	3
17c-7,36;T-36	103	-	-	-	-	-	-	-	35
17c-20,13;T-13	168	-	-	-	-	-	-	-	63
17c-9,31;T-31	4	-	-	-	-	-	-	-	4
17c-9,32;T-32	9	-	-	-	-	-	-	-	6
17c-9,33;T-33	19	-	-	-	-	-	-	-	8
WABASH-EEL									
17b-1,13;EL-13	381	1	7	167	1,357	2,010	3,534	124	20
WABASH-SUGAR CREEK									
17f-10,4;SC-4	66	3	34	873	7,073	4,207	12,153	126	-
17f-5,13;SC-13	91	-	-	-	-	-	-	-	17
17f-2-3,14;SC-14	74	-	-	-	-	-	-	-	38
WABASH-PATOKA									
17i-12,12;P-12	14	2	6	175	1,418	3,753	5,346	135	-
17i-9,15;P-15	18	4	7	175	1,418	6,530	8,123	332	6
17i-7,18;P-18	5	1	3	70	567	1,155	1,792	87	2
17i-6,20;P-20	18	2	6	171	1,383	7,961	9,515	469	-
17i-6,21;P-21	83	4	14	392	3,178	19,009	22,579	926	-
17i-4,22;P-22	68	15	33	811	6,579	41,532	48,922	1,390	19
17i-3,32;P-32	14	3	10	217	1,756	13,756	15,729	437	4
17i-3,34;P-34	21	2	6	140	1,131	8,567	9,838	234	7

TABLE 25 (Cont'd)

POTENTIALLY FEASIBLE WATERSHED PROJECTS

Watersheds[1]	Area in Watershed (Sq Mi)	Number of Structures	Drainage Area Controlled (Sq Mi)	Storage Capacity Sediment (Ac Ft)	Storage Capacity Floodwater (Ac Ft)	Storage Capacity Other Uses (Ac Ft)	Total Capacity (Ac Ft)	Water Surface Area (Acres)	Channel Improvement (Miles)
WABASH-WEST FORK WHITE									
17h1,49,2;W-2	38	2	9	210	1,682	2,238	4,130	288	8
17h1,45,9;W-9	132	3	8	206	1,655	3,844	5,705	285	-
17h1-40,15;W-15	27	3	12	290	2,348	8,932	11,570	321	-
17h1-38,16;W-16	58	8	23	534	4,325	32,350	37,209	906	-
17h1-37,17;W-17	108	17	46	1,075	8,707	51,223	61,005	1,619	-
17h1a-17,23;W-23	55	6	31	684	5,538	37,470	43,692	1,534	-
17h1a-16,24;W-24	24	2	4	81	659	2,866	3,606	192	-
17h1a-15,25;W-25	4	1	3	76	592	1,622	2,290	69	-
17h1a-11,30;W-30	67	6	24	683	5,527	14,415	20,625	676	-
17h1a-10,31;W-31	28	5	12	270	2,184	12,951	15,405	599	-
17h1a-9,32;W-32	7	1	4	52	423	497	972	63	-
17h1a-8,33;W-33	38	4	17	392	3,178	22,979	26,549	873	-
17h1a-7,34;W-34	11	1	4	103	836	2,395	3,334	154	-
17h1a-6,35;W-35	40	4	18	453	3,671	10,252	14,376	422	-
17h1a-3,36;W-36	292	14	50	794	6,430	7,118	14,342	868	53
17h1a-4,37;W-37	91	1	43	1,170	9,475	24,118	34,763	814	-
17h1a-1-2,38;W-38	331	19	225	5,697	46,136	174,094	225,927	3,475	-
17h1-32,40;W-40	58	6	31	677	5,480	26,452	32,609	965	-
17h1-31,41;W-41	50	3	36	754	6,102	6,514	13,370	180	-
17h1-30,43;W-43	24	1	13	317	2,567	10,538	13,422	292	-
17h1-24,48;W-48	12	1	3	56	452	3,459	3,967	67	-
17h1-25,52;W-52	11	1	5	111	903	3,096	4,110	75	-
17h1-25,54;W-54	16	3	6	120	970	7,318	8,408	211	-
17h1-24,55;W-55	7	1	2	49	399	2,922	3,370	93	-
17h1-23,57;W-57	92	10	40	748	6,055	33,715	40,518	1,110	-
17h1-19,59;W-59	23	2	3	65	524	3,239	3,828	167	-
17h1-20,60;W-60	306	7	117	2,968	24,039	14,684	41,691	311	-
17h1-19,61;W-61	59	5	36	795	6,435	21,542	28,772	665	-
17h1-18,62;W-62	16	2	7	142	1,153	3,174	4,469	150	-
17h1-17,65;W-65	18	1	7	173	1,400	2,764	4,337	24	-
17h1-12,72;W-72	320	1	42	1,067	8,707	2,939	12,713	127	46
17h1-3,84;W-84	103	-	-	-	-	-	-	-	4
17h1-1,86;W-86	98	-	-	-	-	-	-	-	48
17h1a-15,89;W-89	12	1	9	221	1,800	11,404	13,425	583	-
17h1a-14,94;W-94	6	1	2	55	449	962	1,466	148	-
WABASH-LITTLE WABASH									
17j1-2;L-2	20	4	9	314	2,544	11,300	14,158	546	-
17j1-3;L-3	10	-	-	-	-	-	-	-	4
17j1-6;L-6	13	-	-	-	-	-	-	-	5
17j1-8;L-8	31	3	8	227	1,841	8,272	10,340	467	-
17j1-9;L-9	32	2	6	162	1,309	771	2,242	90	12
17j1-7;L-7	36	1	4	73	594	969	1,636	164	16
17j1-10;L-10	14	-	-	-	-	-	-	-	7
17j1-11;L-11	6	1	3	74	599	3,312	3,985	218	-
17j1-12;L-12	226	4	32	805	6,518	3,293	10,616	395	74
17j1-14;L-14	36	1	3	96	781	1,593	2,470	141	15
17j1-15;L-15	79	4	47	1,438	11,652	12,846	25,936	762	-
17j1-18;L-18	108	5	42	1,241	10,057	17,986	29,284	1,105	-
17j1-21;L-21	57	2	20	678	5,496	10,245	16,419	574	-
17j1-22;L-22	262	6	131	4,012	32,505	64,656	101,173	2,418	-
17j-27;L-27	35	1	4	144	1,165	7,687	8,996	295	-
17j-29;L-29	38	2	5	201	1,631	4,195	6,027	203	-
17j-34;L-34	277	13	182	6,200	50,234	743,812	800,246	2,956	-
17j-39;L-39	195	6	84	2,844	23,043	19,213	45,100	1,121	-
17j-42;L-42	312	8	144	4,200	34,030	18,808	57,038	1,174	-
17j-44;L-44	30	2	9	313	2,535	2,897	5,745	144	-
17j-45;L-45	47	1	26	538	4,361	2,046	6,945	117	-
17j-46;L-46	52	2	35	2,252	18,287	1,896	22,435	371	-
17j-50;L-50	67	1	9	289	2,341	1,344	3,974	35	-
17j-51;L-51	94	4	60	2,282	18,487	11,721	32,490	622	-
17j-52;L-52	387	10	171	3,431	27,695	56,877	88,003	1,138	-
WABASH-MAIN STEM									
17-125,1;M-1	254	10	146	3,607	29,209	46,943	79,759	2,711	42
17-121,3;M-3	16	1	6	200	1,619	3,954	5,773	306	10
17-118,5;M-5	21	2	8	270	2,185	10,757	13,212	587	-
17-110,11;M-11	36	-	-	-	-	-	-	-	15
17-107,14;M-14	77	-	-	-	-	-	-	-	11
17-103,19;M-19	24	2	8	210	1,701	4,069	5,980	81	-
17-102,20;M-20	18	1	5	129	1,048	2,100	3,277	27	-
17-99,23;M-23	8	1	1	29	230	1,113	1,372	85	-
17-93,29;M-29	38	8	16	430	3,479	4,779	8,688	478	10
17-88,33;M-33	42	1	9	280	2,267	7,453	10,000	301	-
17-87,34;M-34	125	8	65	1,663	13,471	10,733	25,867	847	34
17-85,35;M-35	17	1	6	181	1,463	2,366	4,010	25	-
17-82,38;M-38	108	4	56	1,653	13,386	31,446	46,485	1,326	-
17-77,42;M-42	96	9	39	937	7,590	14,218	22,745	677	-
17-76,43;M-43	43	2	29	822	6,657	18,665	26,144	646	-
17-75,44;M-44	97	4	59	1,354	10,967	21,301	33,622	1,193	-
17-71,47;M-47	124	7	52	1,228	9,943	32,094	43,265	1,203	-
17-70,48;M-48	15	1	6	129	1,041	2,425	3,595	166	-
17-68,50;M-50	25	3	16	368	2,978	10,802	14,148	348	-
17-52,65;M-65	64	-	-	-	-	-	-	-	31
17-46,69;M-69	52	1	47	1,184	9,590	3,060	13,834	81	9
17-39,76;M-76	11	-	-	-	-	-	-	-	8
17-39,77;M-77	29	-	-	-	-	-	-	-	16
17-36,78;M-78	318	-	-	-	-	-	-	-	127
17-34,80;M-80	13	-	-	-	-	-	-	-	7
17-34,82;M-82	29	-	-	-	-	-	-	-	9

TABLE 25 (Cont'd)

POTENTIALLY FEASIBLE WATERSHED PROJECTS

Watersheds (1)	Area in Watershed (Sq Mi)	Number of Structures	Drainage Area Controlled (Sq Mi)	Storage Capacity Sediment (Ac Ft)	Storage Capacity Floodwater (Ac Ft)	Storage Capacity Other Uses (Ac Ft)	Total Capacity (Ac Ft)	Water Surface Area (Acres)	Channel Improvement (Miles)
WABASH-MAIN STEM (Cont'd)									
17-31,85;M-85	22	-	-	-	-	-	-	-	3
17-31,87;M-87	61	-	-	-	-	-	-	-	13
17-117,100;M-100	271	9	61	2,071	16,807	25,519	44,397	1,228	-
17-68,101;M-101	8	1	3	64	515	493	1,072	30	-
17-120,4;M-4	100	7	12	317	2,568	14,030	16,915	746	-
17-102,21;M-21	105	-	-	-	-	-	-	-	7
17-73,45;M-45	27	4	10	303	2,452	7,288	10,043	242	-
17-55,55;M-55	264	2	77	1,981	16,045	4,905	22,931	171	-
17-69,49;M-49	341	4	82	1,931	15,639	2,942	20,512	332	20
WABASH-EAST FORK WHITE									
17h2-46,1;E-1	18	3	9	263	2,130	9,258	11,651	616	-
17h2-45,2;E-2	35	4	14	262	2,124	6,283	8,669	229	7
17h2-44,3;E-3	5	1	2	51	414	1,182	1,647	115	-
17h2-40,7;E-7	18	3	9	207	1,677	8,540	10,424	516	-
17h2-40,9;E-9	19	3	4	99	801	3,086	3,986	314	-
17h2-41,10;E-10	329	9	171	3,977	32,208	6,374	42,559	1,709	12
17h2-37,13;E-13	22	1	13	309	2,505	14,901	17,715	903	4
17h2-36,14;E-14	68	7	19	430	3,482	26,105	30,017	333	-
17h2-34,15;E-15	170	10	42	1,014	8,215	31,514	40,743	921	-
17h2-24,18;E-18	97	4	36	754	6,107	32,279	39,140	735	-
17h2-20,23;E-23	17	2	7	144	1,168	9,448	10,760	289	-
17h2(b)-7,27;E-27	26	2	10	227	1,842	6,130	8,199	413	-
17h2(b)-2,28;E-28	35	1	25	625	5,063	4,839	10,527	440	-
17h2(b)-1-2,30;E-30	437	19	269	2,529	20,480	164,396	187,405	6,735	64
17h2(b)-3,32;E-32	317	3	13	318	2,576	4,615	7,509	233	-
17h2-33,35;E-35	11	1	5	99	802	6,852	7,753	108	-
17h2-33,37;E-37	54	3	26	545	4,415	23,618	28,578	740	-
17h2-29,30,38;E-38	200	1	1	187	1,514	9,600	11,301	272	-
17h2-17,39;E-39	4	2	3	65	528	3,919	4,512	131	-
17h2-15,42;E-42	94	9	70	1,669	13,961	48,934	64,564	3,207	-
17h2-15,43;E-43	15	-	-	-	-	-	-	-	8
17h2-13,44;E-44	12	-	-	-	-	-	-	-	10
17h2-11,46;E-46	43	2	17	451	3,652	1,702	5,805	59	-
17h2-10,48;E-48	18	3	7	146	1,181	7,270	8,597	574	-
17h2-6,50;E-50	20	-	-	-	-	-	-	-	9
17h2-5,52;E-52	80	2	13	178	1,437	2,891	4,506	312	28
17h2-8,55;E-55	13	1	7	145	1,176	7,837	9,158	263	-
17h2(a)-2,62;E-62	389	2	57	1,349	10,888	15,828	28,065	661	-
17h2-28,66;E-66	190	3	12	258	2,091	15,845	18,194	408	-
17h2-44,67;E-67	7	1	3	80	645	2,884	3,609	185	-
17h2-17,68;E-68	9	4	3	83	669	4,668	5,420	163	-
17h2-22,70;E-70	18	1	12	250	2,025	1,033	3,308	19	-
17h2-40,74;E-74	5	1	2	40	324	2,171	2,535	91	-
17h2-8,49;E-49	59	1	12	303	2,455	2,988	5,746	40	12
17h2(b)-8,25;E-25	34	5	13	265	2,143	668	3,076	107	12
WABASH-BIG RACCOON									
17-65,3;B-3	154	17	-	1,472	11,922	3,268	16,662	565	43
17-62,4;B-4	208	6	108	1,275	10,323	6,687	18,285	911	10
CUMBERLAND									
Ky.									
20-6	30	2	16	303	2,599	4,834	7,736	174	-
20-7	93	8	55	1,320	11,143	15,666	28,129	659	6
20-10	44	1	11	159	1,343	3,276	4,778	118	3
20-18	21	2	8	161	1,360	14,470	15,991	375	-
20-20	46	5	19	334	2,819	29,668	32,821	1,007	12
20-28	24	1	16	217	1,835	9,718	11,770	269	2
20-29	25	5	16	229	1,933	16,297	18,459	421	5
20-35	113	6	64	1,214	10,248	44,325	55,787	1,404	12
20-37	25	3	8	159	1,343	12,051	13,553	420	10
20-40	24	3	10	143	1,208	8,287	9,638	235	-
20-46	30	4	16	257	2,168	3,341	5,766	232	-
20-66	67	12	42	624	5,272	14,553	20,449	490	-
20-71	128	7	47	661	5,585	24,984	31,230	1,365	12
20-72	37	2	14	199	1,683	6,849	8,731	360	6
20b-2	122	7	32	430	3,634	48,642	52,706	1,237	5
20b-3	44	5	21	294	2,479	24,417	27,190	809	4
Tenn.									
20-2	38	1	18	286	2,417	362	3,065	102	13
20-10	30	6	17	557	4,703	37,948	43,208	1,177	11
20-14	116	5	39	1,144	9,662	70,651	81,457	1,327	27
20-20	59	3	17	547	4,623	25,888	31,058	525	16
20-21	64	7	40	1,299	10,973	45,846	58,118	828	20
20-35	74	13	52	1,654	13,962	107,741	123,357	3,060	29
20-36	60	2	12	366	3,092	16,556	20,014	1,418	16
20-37	63	1	17	572	4,833	584	5,989	378	58
20-38	36	1	15	501	4,233	4,313	9,047	-	8
20-44	108	15	53	1,701	14,360	105,188	121,249	4,930	22
20-45	63	4	9	303	2,560	23,549	26,412	630	14
20-46	131	16	60	1,918	16,191	110,614	128,723	3,198	30
20-54	175	16	93	3,022	25,516	236,549	265,087	7,657	33
20-55	52	7	37	1,199	10,131	54,972	66,302	1,534	16
20d-4	43	3	12	371	3,137	30,106	33,614	1,531	17
20d-8	18	1	7	209	1,768	12,014	13,991	1,133	5
20d-10	240	8	103	1,603	13,537	32,848	47,988	1,943	70

TABLE 25 (Cont'd)

POTENTIALLY FEASIBLE WATERSHED PROJECTS

Watersheds(1)	Area in Watershed (Sq Mi)	Number of Structures	Drainage Area Controlled (Sq Mi)	Storage Capacity Sediment (Ac Ft)	Storage Capacity Floodwater (Ac Ft)	Storage Capacity Other Uses (Ac Ft)	Total Capacity (Ac Ft)	Water Surface Area (Acres)	Channel Improvement (Miles)
CUMBERLAND (Cont'd)									
Tenn. (Cont'd)									
20d1-1	52	1	19	563	4,752	5,101	10,416	-	10
20d1-2	35	1	13	424	3,579	29,202	33,205	1,215	9
20d1-3	309	9	106	3,197	28,432	142,185	173,814	7,261	36
20e-1	134	7	64	2,052	17,327	122,093	141,472	3,027	28
20e-4	47	1	13	419	3,539	33,395	37,353	985	8
20e-7	66	2	37	950	8,019	36,117	45,086	1,430	18
20f-1	117	12	55	1,784	15,063	120,737	137,584	4,669	25
20f-2	81	3	31	986	8,325	2,022	11,333	348	27
20f-3	221	14	73	2,386	20,142	93,741	116,269	5,206	34
20g-1	262	6	41	1,322	11,165	33,407	45,894	638	20
20g-2	129	6	33	1,072	9,048	46,178	56,298	1,541	20
20g-3	218	14	90	2,889	24,389	108,729	136,007	3,110	58
OHIO MINOR TRIBUTARIES									
Ill.									
18-2	27	2	11	302	2,013	5,154	7,469	280	7
18-3	11	2	8	195	1,300	3,650	5,145	214	-
18-7	272	12	134	4,148	27,637	31,626	63,411	3,035	24
18-8	245	6	27	868	5,782	10,861	17,511	1,232	31
18-10	28	-	-	-	-	-	-	-	10
18-13	13	-	-	-	-	-	-	-	5
18-14	244	8	53	1,759	11,717	20,467	33,943	2,391	50
18-18	14	-	-	-	-	-	-	-	7
22-1	303	15	91	2,538	16,912	30,925	50,375	2,793	56
00-11	21	2	12	308	2,052	5,358	7,718	347	2
00-13	22	3	7	172	1,148	2,996	4,316	172	3
00-14	220	7	95	2,804	18,683	-	21,487	1,181	51
00-16	91	3	35	1,055	7,030	17,642	25,727	844	-
00-17	84	11	51	1,361	9,069	23,264	33,694	1,463	-
00-19	9	1	4	114	757	2,034	2,905	98	5
00-21	42	6	24	625	4,165	10,065	14,855	770	-
00-25	16	1	5	144	957	2,551	3,652	175	6
Ind.									
07-2	47	-	-	-	-	-	-	-	15
07-4	32	6	6	189	1,256	11,001	12,446	532	12
07-5	359	10	33	975	6,494	11,033	18,502	1,045	24
07-7	67	4	15	486	3,238	6,188	9,912	886	10
07-8c	6	1	2	56	376	748	1,180	111	2
07-8d	38	6	11	362	2,140	6,771	9,273	680	14
07-8e	31	3	5	150	1,002	2,539	3,691	291	9
07-8f	39	5	7	219	1,457	7,334	9,010	585	9
07-9	330	28	114	3,725	24,818	296,088	324,631	8,257	62
07-10	67	7	20	515	3,433	3,575	7,523	243	13
07-15	158	28	50	1,470	9,793	32,123	43,386	2,151	50
LH-1a	12	-	-	-	-	-	-	-	5
LH-1b	2	-	-	-	-	-	-	-	2
LH-1c	3	-	-	-	-	-	-	-	2
LH-1d	9	-	-	-	-	-	-	-	7
LH-1e	6	-	-	-	-	-	-	-	2
LH-1f	20	-	-	-	-	-	-	-	11
LH-1g	11	-	-	-	-	-	-	-	5
LH-1h	15	-	-	-	-	-	-	-	9
LH-1j	10	-	-	-	-	-	-	-	7
LH-1k	29	-	-	-	-	-	-	-	21
LH-3	13	-	-	-	-	-	-	-	2
LH-5	7	-	-	-	-	-	-	-	5
LH-7	20	-	-	-	-	-	-	-	11
LH-8	20	-	-	-	-	-	-	-	8
LH-9	29	-	-	-	-	-	-	-	15
LH-10	21	3	6	160	1,064	6,229	7,453	543	-
LH-11	73	-	-	-	-	-	-	-	18
LH-12	13	-	-	-	-	-	-	-	5
LH-14	145	18	59	1,906	12,697	61,215	75,818	2,470	-
LH-15	8	1	6	166	1,103	9,204	10,473	294	-
LH-17	52	8	30	932	6,207	31,990	39,129	1,322	-
LH-20	19	1	1	41	270	2,583	2,894	98	-
LH-21	72	2	8	238	1,588	5,578	7,404	209	-
LH-22	146	11	34	1,095	7,296	36,632	45,023	1,239	-
LH-23	26	1	8	167	1,113	4,280	5,560	221	-
LH-30	254	17	116	3,765	25,086	35,608	64,459	2,116	10
LH-[illegible]	100	2	19	570	3,801	12,752	17,123	497	-
LH-32	29	2	9	294	1,960	7,433	9,687	251	-
LH-35	5	1	2	47	316	1,589	1,952	52	-
Ky.									
19-2	15	1	8	159	1,061	2,332	3,552	258	5
19-3	28	7	9	197	1,311	5,008	6,516	405	5
19-8	210	7	110	2,626	17,494	21,620	41,740	3,924	33
19-9	61	5	33	1,519	10,121	7,282	18,922	847	17
0-1	253	13	74	1,797	11,973	94,712	108,482	2,049	30
0-5	16	3	9	255	1,696	5,365	7,316	240	-
0-7	53	1	34	992	6,608	11,982	19,582	486	-
0-8	59	2	40	979	6,521	9,015	16,515	343	-
0-12	28	3	18	315	2,100	12,960	15,375	330	-
0-25	50	7	28	484	3,226	28,883	32,593	858	10
0-26	74	7	22	475	3,166	9,057	12,698	799	22

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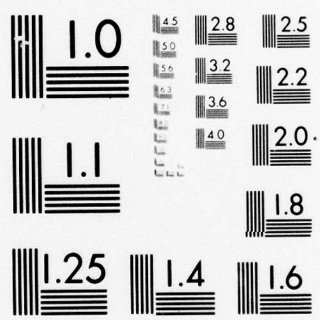

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE 25 (Cont'd)

POTENTIALLY FEASIBLE WATERSHED PROJECTS

Watersheds[1]	Area in Watershed (Sq Mi)	Number of Structures	Drainage Area Controlled (Sq Mi)	Storage Capacity Sediment (Ac Ft)	Storage Capacity Floodwater (Ac Ft)	Storage Capacity Other Uses (Ac Ft)	Total Capacity (Ac Ft)	Water Surface Area (Acres)	Channel Improvement (Miles)
OHIO MINOR TRIBUTARIES (Cont'd)									
Ky. (Cont'd)									
0-28	34	6	9	169	1,126	21,199	22,494	1,324	-
0-30	150	9	62	1,706	11,365	5,080	18,151	1,828	17
0-33	96	1	6	137	913	1,855	2,905	210	12
0-34	50	2	36	676	4,417	8,424	13,517	454	-
0-35	20	2	8	141	939	20,398	21,478	634	6
0-36	20	4	8	147	981	11,058	12,186	697	5
0-37	55	9	23	424	2,822	35,237	38,483	1,449	12
0-38	38	3	26	459	3,061	15,822	19,342	628	8
0-40	75	5	28	488	3,252	4,188	7,928	858	8
1a	24	4	12	285	1,896	11,549	13,730	386	-
2c	16	3	7	180	1,200	10,180	11,560	303	-
2e	21	4	11	255	1,696	10,650	12,601	307	5
3a	154	7	39	865	5,765	46,935	53,565	1,690	20
5a	68	5	30	824	5,487	15,583	21,894	614	-
7a	55	4	30	737	4,913	10,563	16,213	480	-
10a	20	2	9	219	1,461	3,042	4,722	149	5
12a	26	3	11	262	1,748	2,651	4,661	147	6
Ohio									
0-8	147	8	25	549	3,655	22,539	26,743	784	-
0-17	221	31	99	2,140	14,258	112,211	128,609	4,952	84
0-18	151	15	31	670	4,463	41,516	46,649	2,197	47
0-19	30	6	7	156	1,036	9,804	10,996	518	18
0-23	16	3	6	137	914	7,071	8,122	260	9
0-27	39	1	8	177	1,176	6,207	7,560	243	10
0-28	185	9	62	1,597	10,643	53,488	65,728	1,470	20
0-29	233	17	56	1,203	8,015	51,674	60,892	1,923	48
0-34	24	-	-	-	-	-	-	-	12
0-36	20	2	5	103	684	472	1,259	53	7
0-43	166	6	17	379	2,527	2,578	5,484	291	32
Penn.									
51	19	3	10	197	1,314	789	2,300	157	-
52	247	3	16	389	2,591	3,838	6,818	214	-
62	202	12	30	578	3,854	2,669	7,101	312	-
W. Va. & Pa.									
0-2	54	3	36	990	6,598	9,259	16,847	406	-
Pa. & W. Va.									
0-7	299	14	212	5,140	34,468	67,490	107,098	2,345	-
0-8	12	1	9	231	1,539	-	1,770	70	-
0-9	67	9	14	395	2,629	4,953	7,977	326	-
0-11	63	2	1	34	228	429	691	46	-
0-14	19	3	7	181	1,206	2,783	4,170	141	-
0-20	43	2	3	67	444	1,033	1,544	87	-
0-22	101	16	24	502	3,345	7,804	11,651	506	-
0-30	64	4	22	527	3,508	8,077	12,112	434	-
0-35	146	16	88	2,119	14,118	15,859	32,096	1,269	-
0-45	15	16	7	189	1,261	1,783	3,233	185	1
0-47	168	-	-	-	-	-	-	-	6
0-48	111	4	8	202	1,346	3,111	4,659	166	17
0-23	113	4	80	1,945	12,961	16,370	31,276	648	-

(1) Watersheds are listed by the National Inventory of Conservation Needs Number; the watersheds are referenced by the same number on the subbasin maps.

TABLE 26

RECREATION POTENTIAL AT RESERVOIRS AND NAVIGATION POOLS

	Corps of Engineers 1965 Reservoir Program				Future Reservoir Program				Total		
Subbasin	Number of Reservoirs	Present Surface Area Pool in Acres	Visitation Annual Visitor Days	Ultimate Visitation Visitor Days (1)	Number of Reservoirs	Surface Area Pool in Acres	Visitation Annual Visitor Days (2)	Ultimate Visitation Visitor Days	Number of Reservoirs	Surface Area Pool in Acres	Ultimate Visitation Visitor Days
Allegheny	10	14,823	3,028,940	13,746,000	7	4,025	2,532,000	6,282,000	17	18,848	20,028,000
Monongahela	2	4,585	1,131,660	2,833,000	8	14,500	2,868,000	6,758,000	10	19,085	9,591,000
Beaver	4	17,650	2,585,050	8,499,000	2	73,000	3,278,000	21,929,000	6	90,650	30,428,000
Muskingum	16	17,975	5,266,800	13,918,400	10	4,528	2,516,450	7,043,700	26	22,503	20,962,100
Little Kanawha	0	0	0	0	4	3,250	1,175,000	2,311,000	4	3,250	2,311,000
Hocking	1	664	554,300	582,000	5	4,465	1,848,300	4,085,300	6	5,129	4,667,300
Kanawha	3	6,213	2,284,100	3,199,000	20	47,260	5,735,800	13,928,800	23	53,473	17,127,800
Guyandotte	1	630	330,000	909,000	10	2,160	222,000	222,000	11	2,790	1,131,000
Big Sandy	4	3,557	1,389,100	1,785,000	5	3,162	1,521,000	2,760,900	9	6,719	4,545,900
Scioto	5	4,665	1,706,400	5,280,000	5	5,624	2,219,000	5,078,000	10	10,289	10,358,000
Little Miami	2	4,990	1,522,000	4,800,000	4	6,250	1,724,000	4,275,000	6	11,240	9,075,000
Great Miami	2	6,270	970,000	3,903,000	6	6,208	2,354,000	5,835,000	8	12,478	9,738,000
Licking	1	8,270	400,000	980,000	3	15,930	1,635,000	3,273,000	4	24,200	4,253,000
Kentucky	5	10,711	1,209,400	3,085,000	11	34,390	5,926,000	14,694,000	16	45,101	17,779,000
Salt	0	0	0	0	4	16,970	2,536,000	5,962,000	4	16,970	5,962,000
Green	4	27,690	1,696,400	6,300,000	1	4,000	598,000	1,485,000	5	31,690	7,785,000
Wabash	6	21,150	2,632,800	11,107,000	29	176,209	19,518,000	51,336,000	35	197,359	62,443,000
Cumberland	6	116,430	9,217,700	15,000,000	9	44,673	4,603,000	11,045,000	15	161,103	26,045,000
Ohio-Minor Tribs	4	3,583	2,673,900	3,700,000	18	9,960	6,930,000	14,779,000	22	13,543	18,479,000
Sub-Total	76	269,856	38,598,550	99,626,400	161	476,564	69,739,550	183,082,700	237	746,420	282,709,100
Streams	Number of Navigation Pools	Present Surface Area Pool in Acres	Visitation Annual Visitor Days	Ultimate Visitation Visitor Days (1)					Number of Navigation Pools (3)	Surface Area Pool in Acres(3)	Ultimate Visitation Visitor Days (3)
Ohio River	21	229,134	4,840,000	19,367,000					19	243,804	20,607,533
Allegheny	8	8,675	131,000	524,000					8	8,675	524,000
Monongahela	9	8,065	120,800	486,900					9	8,612	519,949
Kanawha	3	5,100	76,000	307,912					3	5,100	307,912
Kentucky	14	13,354	201,000	806,247					14	13,354	806,247
Green	5	7,521	113,000	454,080					5	7,521	454,080
Cumberland	4	99,830	7,623,000	9,750,000					4	99,830	9,750,000
Sub-Total	64	371,679	13,104,800	31,696,139					62	386,896	32,969,721
TOTAL		641,535	51,703,350	131,322,539		475,564	69,739,550	183,082,700		1,133,316	315,678,821

(1) Lands available, requires additional facilities.
(2) Based on 1965 supply and demand.
(3) Changes in totals reflect completion of the Ohio River modernization program.

TABLE 27

RECREATION OPPORTUNITIES PROVIDED IN POTENTIAL USDA RESOURCE DEVELOPMENT PROGRAM

Subbasin	Recreation Water Area (Acres) In Watersheds Projects	Outside Watersheds(1) Projects	Totals	Recreation Days Provided In Watersheds Projects	Outside Watersheds(1) Projects	Totals
Allegheny	9,520	31,440	40,960	4,760,000	15,330,000	20,090,000
Monongahela	3,640	11,580	15,220	1,820,000	5,530,000	7,350,000
Beaver	2,070	380	2,450	1,040,000	100,000	1,140,000
Muskingum	11,700	6,280	17,980	5,850,000	2,640,000	8,490,000
Little Kanawha	170	640	810	90,000	220,000	310,000
Hocking	980	24,400	25,380	490,000	12,150,000	12,640,000
Kanawha	6,700	25,140	31,840	3,360,000	12,070,000	15,430,000
Guyandotte	1,760	170	1,930	880,000	50,000	930,000
Big Sandy	7,440	5,940	13,380	3,720,000	2,900,000	6,620,000
Scioto	7,500	10,780	18,280	3,750,000	4,280,000	8,030,000
Little Miami	2,140	1,800	3,940	1,080,000	420,000	1,500,000
Great Miami	5,200	3,130	8,330	2,600,000	730,000	3,330,000
Licking	4,890	3,880	8,770	2,440,000	2,480,000	4,920,000
Kentucky	9,100	10,160	19,260	4,500,000	3,940,000	8,440,000
Salt	5,610	3,450	9,060	2,810,000	970,000	3,780,000
Green	24,750	15,540	40,290	12,390,000	3,730,000	16,120,000
Wabash	55,500	31,390	86,890	27,680,000	13,420,000	41,100,000
Cumberland	31,600	23,770	55,370	15,800,000	8,670,000	24,470,000
Ohio - Minor Tributaries	47,400	70,650	118,050	23,700,000	29,850,000	53,550,000
Total Basin	237,670	280,520	518,190	118,760,000	119,480,000	238,240,000

RECREATION OPPORTUNITIES PROVIDED IN USDA GOING PROGRAM

	Recreation Days Provided
Watershed Program------------------------------	1,150,935
Farm Ponds & Private Recreation Developments--	10,500,000
National Forest--------------------------------	3,456,000
Total--------------------------	15,106,935

(1) Includes other USDA Development Programs and National Forest Projected Development.

TABLE 28

IDENTIFIED POTENTIAL HYDROELECTRIC POWER SITES

Subbasin	Conventional and Pumped Storage No. of Sites	Installed Capacity (kw)	Average Annual Generation (mwh)	Range of Gross Head (ft)
Allegheny	3	565,000	905	150-798
Monongahela	9	1,222,000	2,431	50-938
Beaver	4	100,000	140	70-120
Kanawha	14	2,100,000	7,250	50-680
Great Miami, Little Miami	3	255,000	347	55-327
Licking, Kentucky, Salt	8	931,300	1,595	25-560
Green	3	102,000	284	38-133
Wabash	7	245,000	780	28-74
Cumberland	7	864,000	894	50-457
Ohio River	16	816,000	4,147	16-35
TOTAL	74	7,200,300	18,773	